DEPARTMENT OF THE ARMY
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REPLY TO
ATTENTION OF

CEHNC-EM 20 December 2013

MEMORANDUM FOR RECORD

SUBJECT: Technical Guidance for Military Munitions Response Actions, Environmental and Munitions Center of Expertise Interim Guidance Document (IGD) 14-01

1. IGD 14-01 provides EM 200-1-15 dated 30 October 2013 (enclosed) for immediate use. All technical and legal reviews have been conducted. While the document is undergoing final formatting review you are encouraged to use this IGD for all technical aspects of munitions response projects.

2. This guidance is applicable to all project and program management districts and design centers executing or managing military munitions response program (MMRP) projects.

3. Project delivery teams are encouraged to transition from referencing and using EM 1110-1-4009 with the understanding, upon final publication, EM 200-1-15 will supersede EM 1110-1-4009. PDTs will need to assess current task orders for any contractual impacts. All future task orders should reference IGD 14-01 or the published EM 200-1-15.

4. This interim guidance remains in effect until final publication of EM 200-1-15. The document will be posted on EKO on the Environmental & Cleanup sub-cop page: https://eko.usace.army.mil/usacecop/environmental/subcops/htrw

5. For additional information, please contact Mr. John Sikes at 256-895-1334.

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US Army Corps of Engineers®

EM 200-1-15
30 October 2013

# ENVIRONMENTAL QUALITY

# TECHNICAL GUIDANCE FOR MILITARY MUNITIONS RESPONSE ACTIONS

## Interim Guidance Document (IGD)

## ENGINEER PAMPHLET

## AVAILABILITY

Electronic copies of this and other U.S. Army Corps of Engineers (USACE) publications are available on the Internet at http://publications.usace.army.mil/publications/ This site is the only repository for all official USACE engineer regulations, circulars, manuals, and other documents originating from HQUSACE. Publications are provided in portable document format (PDF).

This document is intended solely as guidance. The statutory provisions and promulgated regulations described in this document contain legally binding requirements. This document is not a legally enforceable regulation itself, nor does it alter or substitute for those legal provisions and regulations it describes. Thus, it does not impose any legally binding requirements. This guidance does not confer legal rights or impose legal obligations upon any member of the public.

While every effort has been made to ensure the accuracy of the discussion in this document, the obligations of the regulated community are determined by statutes, regulations, or other legally binding requirements. In the event of a conflict between the discussion in this document and any applicable statute or regulation, this document would not be controlling.

This document may not apply to a particular situation based upon site-specific circumstances. USACE retains the discretion to adopt approaches on a case-by-case basis that differ from those described in this guidance where appropriate and legally consistent.

This document may be revised periodically without public notice.

CEMP-CE

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

EM 200-1-15

Manual
No. 200-1-15

30 October 2013

Environmental Quality

# TECHNICAL GUIDANCE FOR MILITARY MUNITIONS RESPONSE ACTIONS

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# CHAPTER 1

## Introduction

1.1. Purpose. This manual provides the United States Army Corps of Engineers (USACE) Project Delivery Team (PDT) with the processes for executing the technical aspects of munitions response (MR) projects. The foundation of Corps of Engineers environmental work is the Environmental Operating Principles as specified in ER 200-1-5. These seven tenets serve as guides and must be applied in all Corps business lines as we strive to achieve a sustainable environment.

1.2. Applicability. This manual applies to all Headquarters, USACE (HQUSACE) elements, USACE commands, and USACE contractors having responsibility for performing MR activities.

1.3. Distribution Statement. Approved for public release; distribution is unlimited.

1.4. References. References are included in Appendix A.

1.5. General.

1.5.1. It is the policy of USACE that USACE organizational elements execute Military Munitions Support Services (M2S2) work in accordance with (IAW) applicable laws, regulations, and policies. M2S2 Military Munitions Response Program (MMRP) projects shall be performed IAW the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); Executive Order (EO) 12580, Superfund Implementation (23 January 1987); the Defense Environmental Restoration Act (DERA); and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Where Resource Conservation and Recovery Act (RCRA) Corrective Actions have been implemented, RCRA may apply.

1.5.2. The organizational structure and the roles and responsibilities of USACE for providing M2S2 are set forth in Engineer Regulation (ER) 1110-1-8153.

1.5.3. The technical guidance provided in this Engineer Manual (EM) applies to all munitions projects, including those investigation and remedial activities conducted under CERCLA (i.e., site inspection [SI], remedial investigation [RI], feasibility study [FS], remedial design [RD], remedial action [RA] as well as removal action activities like engineering evaluation/cost analysis [EECA], removal design [RmD], time-critical removal action [TCRA], and non-time-critical removal action [NTCRA]). This technical manual also can be used as guidance for munitions-related actions under other regulatory frameworks and in support of other programs and projects. It is intended to support existing MR policy and guidance.

1.5.4. This manual provides the USACE PDT with the processes for executing the technical aspects of MR projects. The PDT includes the Project Manager (PM), technical experts within or outside the local USACE activity, specialists, consultants/contractors, the customer(s), stakeholders, representatives from other federal and state agencies, and vertical members from division and headquarters that are necessary to effectively develop and deliver the project.

1.5.5. This EM is divided into chapters representing the major components of an MR project that require PDT consideration.

1.5.6. The engineering considerations presented in this EM address primarily the actions taken to reduce the explosives safety hazards associated with munitions and explosives of concern (MEC) and the human health and environmental risks associated with munitions constituents (MC). For additional information, review the USACE Web site for new guidance (http://publications.usace.army.mil/publications/). Review also the USACE Environmental and Munitions Center of Expertise (EM CX) Web site and the M2S2 Web site on Engineering Knowledge Online for additional information. Other relevant guidance is contained in (but not limited to) the following documents:

1.5.6.1. For Chemical Warfare Materiel (CWM), see Engineer Pamphlet (EP) 75-1-3.

1.5.6.2. Health and safety aspects of explosives safety and information on responsibilities and procedures for dealing with material potentially presenting an explosive hazard (MPPEH) are provided in EM 385-1-97.

1.5.6.3. For Formerly Used Defense Sites (FUDS) and for guidance on obtaining rights of entry (ROEs), see ER 200-3-1.

1.5.6.4. For information on Land Use Controls (LUCs), see EP 1110-1-24 and ER 200-3-1.

1.5.6.5. Guidance on stakeholder involvement under the Technical Project Planning (TPP) process is contained in EM 200-1-2, and guidance on public participation is contained in EP 200-3-1.

1.5.7. For projects that deal with depleted uranium munitions, the PDT should refer to the requirements contained in regulations codified at Title 10 of the CFR Part 20, Army Regulation 385-10, and All Army Activities Message (ALARACT) 188/2011.

1.5.8. Consult relevant Department of Defense (DoD), Army, and USACE Interim Guidance Documents (IGDs) and apply information to the appropriate aspects of project planning and/or execution (see http://www.hnd.usace.army.mil/oew/interimguid.aspx). Guidance contained in IGDs may change as the guidance is finalized; therefore, project personnel (including the PDT and contractors) must keep abreast of all recent changes to Army policy and guidance that are relevant to their project.

1.5.9. Other resources are available that may provide information to assist PDTs. In instances where these resources conflict with this or other formal DoD or service guidance, the formal guidance should be followed. These resources are considered related (non-essential) and are not required. It is recommended that PDT members familiarize themselves with the available information to make salient technical recommendations specific to their project data quality objectives (DQOs), particularly in areas where the science is evolving. Some examples of related resource documents are presented in Appendix A.

1.5.10. Commercially available equipment and software are referenced throughout this document. The government does not express nor imply preference for any of these mentioned systems but merely provides them as examples for informational purposes only.

1.6. EM 200-1-15 Overview.

1.6.1. Numbering Convention. Since the last revision of this manual in 2007, USACE is in the process of publishing updates to a number of the EMs, EPs, ERs, and other guidance cited in the 2007 version. These updates include content revisions as well as assigning new numbers to some of the guidance documents. A crosswalk between the old and new numbering conventions is provided in Table 1-1. This manual uses the new numbering convention.

Table 1-1: Changes to Document Numbers for EMs, EPs, and ERs

| **Prior Document No.** | **New Document No.** | **Document Title** |
|---|---|---|
| EP 75-1-4 | EP 200-1-18 | Environmental Quality: Five-year Reviews of Military Munitions Response Projects |
| EP 1110-1-24 | EP 200-1-20 | Land Use Controls |
| EP 1110-3-8 | EP 200-3-1 | Environmental Quality: Public Participation Requirements for Defense Environmental Restoration Program |
| EM 1110-1-4007 | EM 200-1-23 | Safety and Health Aspects of Hazardous, Toxic, and Radioactive Waste Remediation Technologies |
| EM 1110-1-4009 | EM 200-1-15 | Military Munitions Response Actions |
| EM 1110-1-1200 | EM 200-1-12 | Conceptual Site Models for Environmental and Munitions Projects |
| EM 1110-1-4000 | EM 200-1-17 | Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites |
| EM 1110-1-4014 | EM 200-1-16 | Environmental Quality: Environmental Statistics |
| ER 1110-1-263 | ER 200-1-7 | Chemical Data Quality Management for Environmental Cleanup |

1.6.2. Locating Information. This manual contains detailed technical guidance on a variety of topics related to MR actions. Table 1-2 is provided to help the user locate specific information of interest. First, identify the general topic area in the first column. Within each general topic area are a number of specific topics associated with that general topic area, which are shown in the second column. The specific topics are listed in alphabetical order. Once the specific topic is found, the relevant section(s), table(s), and figure(s) where guidance on the topic is located are shown in the third column of Table 1-2.

Table 1-2: Information Locations by Topic Area

| General Topic Area | Specific Topic | Relevant Section(s) |
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| | EMI Sensors | 6.3.7.2; Tables 6-1, and 6-2 |
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| | Magnetometers | 6.3.7.1; Tables 6-1, 6-2, 6-3, and 6-5 |
| | Marine Geophysical Sensors | 6.3.7.5; Table 6-2 |
| | MEC Detectability | 6.6.2.5 |
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| | Positional Accuracy and Precision | 6.4.1; 6.4.2; 6.4.3; Figure 6-19 |
| | Positioning Options | 6.4.4; Figure 6-20; Figure 6-21; Figure 6-22; Figure 6-23; Figure 6-24; Figure 6-25 |
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| General Topic Area | Specific Topic | Relevant Section(s) |
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| General Topic Area | Specific Topic | Relevant Section(s) |
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| General Topic Area | Specific Topic | Relevant Section(s) |
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| General Topic Area | Specific Topic | Relevant Section(s) |
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| General Topic Area | Specific Topic | Relevant Section(s) |
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| General Topic Area | Specific Topic | Relevant Section(s) |
|---|---|---|
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Note: Refer to Glossary for definition of acronyms.

# CHAPTER 2

## Project Planning and Execution

2.1. Project Delivery Team.

2.1.1. The PDT is empowered with the authority and responsibility for achieving the DoD's environmental restoration objectives and delivering quality products and services. The PDT includes the PM, technical experts within or outside the local USACE activity, specialists, consultants/contractors, the customer(s), stakeholders, representatives from other federal and state agencies, and vertical members from division and headquarters who are necessary to effectively develop and deliver the project. Where PDT involvement is specified in this document, the PM will be responsible for determining specifically which members of the PDT should be involved in each particular part of the process. The PDT will implement the public involvement requirements specified in EP 200-3-1 during the planning phase.

2.1.2. USACE Military Munitions Design Centers (MMDCs) are responsible for providing technical services to the PDT for addressing a site's environmental and safety risks associated with the presence of MEC and MC, unless otherwise delegated, as specified in ER 1110-1-8153.

2.1.3. For CWM projects, the Ordnance and Explosives Chemical Warfare Materiel Design Center (CWM DC) provides specialized support to assist HQUSACE, USACE Commands, Field Operating Activities (FOAs), and laboratories by executing chemical warfare materiel responses and maintaining state-of-the-art technical expertise for all aspects of CWM DC response activities. The CWM DC is the only Design Center authorized to execute any phase of a CWM project.

2.1.4. The expertise and disciplines of the people on the PDT will depend on the nature and phase of the project. When assembling the PDT, the PM should consider including individuals with expertise in the following types of technical disciplines, depending on need: biology, chemistry, hydrology, hydrogeology, geology, risk assessment, environmental engineering, geophysics, geographical information systems (GIS) and mapping, and unexploded ordnance (UXO) safety and industrial hygiene. Other specialty areas may include contracting, office of counsel, public affairs, real estate, health physics, cost estimation, regulatory compliance, and archeology.

2.2. Technical Project Planning.

2.2.1. TPP is a comprehensive planning process performed IAW EM 200-1-2. The TPP process, along with the associated planning documents, helps the PDT determine and document the project's DQOs and the types, quantities, and quality of data that are required to meet the DQOs and aid in the preparation of an accurate and complete conceptual site model (CSM). The U.S. Environmental Protection Agency (USEPA) DQO process is a seven-step process that begins with a problem statement, identifies a hypothesis and the decisions that need to be made (i.e., goals of the study), and then identifies information inputs, boundaries of the study area, analytical approach, performance or acceptance criteria, and finally, a detailed plan for obtaining data. See Appendix E of EM 200-1-2 for a cross walk between the TPP process and the USEPA's seven-step DQO process. The TPP process also can be used to develop and update the Uniform Federal Policy for Quality Assurance Project Plan (UFP-QAPP) for the project. The PDT prepares various planning worksheets, as described in EM 200-1-2. The TPP process should be used iteratively; that is, it should be used as a data feedback loop that allows project objectives and data collection programs to be evaluated continually as site knowledge increases and project uncertainty decreases.

2.2.2. The TPP process is an approach involving a series of meetings during which the project goals and objectives, the CSM, project data needs and data collection methods, and DQOs are discussed and agreed upon by project stakeholders. The project team can and should approach the various phases of the TPP process simultaneously when it makes sense.

2.2.3. The TPP process is not a replacement for less formal regular or ad hoc meetings undertaken by the PDT that are necessary to achieve the objectives of the project. The following sections provide an overview on the four phases of the TPP process.

2.2.3.1. <u>Phase I – Define Project</u>.

2.2.3.1.1. The first phase of the TPP process defines the overall objective(s) for the project. Project objectives are those long-term and short-term issues that must be resolved, as well as other related project objectives that will need to be resolved to close the site or achieve phase completion. Although TPP is an iterative process and project objectives may be refined, deleted or added as necessary, the PDT should clearly define the project objectives at the beginning of the process because all other elements of the TPP process are established based on this initial step and project objectives support subsequent project decisions.

2.2.3.1.2. Available project property data are gathered during Phase I of the TPP process. EM 200-1-2 provides a worksheet for identifying the data that need to be gathered. These data are used to prepare the preliminary CSM, which is used to identify data needs during the second phase of the TPP process. The CSM is a written and/or pictorial representation of current site conditions and processes based on available information (e.g., contaminant migration, leaching to groundwater, potential receptor activities). USACE EM 200-1-12, Conceptual Site Models for Environmental and Munitions Projects is the USACE guide for developing CSMs. The necessary elements of a CSM describe all aspects of a munitions response site (MRS) and include the Facility Profile (e.g., type of range), Physical Profile (e.g., location and areal extent of UXO, depth of UXO), and Land Use and Exposure Profile (e.g., ecological and cultural resources profile, pathway analysis). For example, a complete MC CSM describes contaminant release mechanisms and locations, age of possible release, physical and chemical properties of MC, and physical transport processes that control migration and degradation of contaminants (which depend on soil type, topography, climate, vegetation, depth to groundwater, and other factors).

2.2.3.1.2.1. The CSM evaluates whether a source-to-receptor pathway exists and is complete for a given MRS and media (e.g., soil and surface water for MEC and MC, groundwater and air for MC). The CSM documents the complete source-to-receptor pathways, which include a source, release mechanisms, exposure potential, and receptors. The PDT should use the CSM as a communication tool to inform project stakeholders of the potential MEC hazards and MC risks at a given MRS. In addition, the CSM helps the PDT determine the project's data needs. A well-developed CSM also shows the data gaps of the site characterization; however, it is important to note that the data gaps do not necessarily equate to the data needs necessary in order to characterize the MRS. For example, a data gap for a site with an anticipated RA within a target area may include not knowing an accurate number of anomalies and an approximate number of UXO present within the target area; however, for an RI at an MRS, the existing data may suffice to determine the nature and extent of the UXO within the target area such that cost estimates for an RA may be estimated to a +50%/-30% margin. The CSM should evolve throughout a project and throughout the project lifecycle as new data are collected and/or as site conditions or receptors change. If changes in site conditions or new data warrant at any point during site characterization activities, the PDT should re-evaluate the CSM for the MRS to determine if modifications to the site characterization approach are warranted. See EM 200-1-12 for more detailed guidance on developing CSMs. Several studies have evaluated the use of the following information sources that PDTs can use to assist with developing CSMs and site characterization approaches (ESTCP - Tinney et al., 2010; ESTCP - Nelson et al, 2008):

- Historical aerial photographs
- Common Operations Reports (see Section 7.14)
- Light Detection and Ranging (LIDAR) and other remote sensing imaging
- Munitions usage data
- Range design drawings and information
- Results from previous investigations (see next section)

2.2.3.1.2.2. Results from previous MC investigations may provide valuable information regarding site characteristics (e.g., soil type, geological stratigraphy, depth to groundwater, groundwater flow direction) as well as MC concentrations and distribution for CSM development. It is important to consider the quality of the analytical data to gauge whether it is of sufficient quality to use in site evaluations (e.g., risk assessments). Data quality considerations include the following:

- Consider background analytical data. Were background soil samples collected from soils derived from the same parent material and processes as soils of site samples? Are soil background data adequate for statistical comparison to the site data?

- Consider sample locations. For instance, were groundwater wells located and constructed to reflect aquifer conditions in areas and at depths likely to be impacted by MC releases?

- Consider sample collection and handling techniques. For instance, what methods were used to collect samples? Were groundwater samples to be analyzed for metals filtered in the field?

- Consider the analytical methods used and the resulting detection limits. Was an appropriate analytical method selected for the MC analyses, and were appropriate quality assurance / quality control (QA/QC) procedures followed? Are the data reporting limits lower than the project screening or action levels?

2.2.3.1.3. Develop Phase I Planning Memo. In addition to the preliminary CSM, documentation produced during this phase of the TPP process includes a Phase I Project Planning Memo, which is prepared by the PDT to document the team's findings and decisions during Phase I. The Phase I Planning Memo should be used to update the Project Management Plan (PMP). Information from the Planning Memo may be used in development of Worksheet #9 of the UFP-QAPP (see Section 4.4 for information on the purpose and content of a UFP-QAPP). The Phase I Planning Memo should clearly document the project and associated project objectives within the context of the overall site approach for the current executable stage of site activities, indicate the customer's goals (i.e., concept of site closeout, schedule requirements, and site budget), and identify site constraints and dependencies.

2.2.3.1.4. Examples of project objectives include, but are not limited to, the following:

- Determine the nature and extent of MEC at the MRS to include horizontal and vertical extent, and determine density of MEC.

- Determine if the remedial action objective (RAO), as outlined in the decision document to remove all MEC to a depth of 2 feet below ground surface, has been accomplished.

- Determine if MC contaminated soils above the cleanup level selected in the decision document have been removed and treated successfully.

- Determine if MC contamination evaluated in the baseline risk assessment (BRA) indicates an unacceptable risk to human health or the environment.

2.2.3.2. Phase II – Determine Data Needs.

2.2.3.2.1. During TPP Phase II, the PDT determines the data needs that need to be met to adequately complete the site characterization; these will form the basis of later DQO development. Types of data that may be needed include determination of the types of UXO and/or discarded military munitions (DMM) present at the MRS, the regulatory requirements, the site's land use, and the physical characteristics of the site. Data should be sufficient to support future decisions, for example, RI data should be sufficient to evaluate remedial alternatives in the FS, to conduct MC human health and ecological risk assessments for all media with a potentially complete source-receptor pathway, to conduct a MEC Hazard Assessment (MEC HA), and to design response actions. Documentation prepared at the end of Phase II should communicate the intended data uses and data needs such as the location/depth of MEC, degree of statistical confidence levels for UXO and geophysical investigation; or for MC the required number of samples, the contaminant concentrations of interest, and the necessary sampling areas or locations and depths. Appendix F of EM 200-1-2 contains tables that may be used to document data needs.

2.2.3.2.2. Examples of data needs may include, but are not limited to, the following:

- Determine the horizontal and vertical extent of MEC in the MRS(s).

- Determine areas of concentrated munitions use and areas of non-concentrated munitions use.

- Determine if MC contamination evaluated in the BRA indicates an unacceptable risk to human health or the environment. For post remediation sampling of MEC, determine if the RAO, as outlined in the decision document to remove all MEC to a depth of 2 feet below ground surface, has been accomplished.

- For post remediation sampling of MC, determine if MC contaminated soils above the cleanup level selected in the decision document have been removed and treated successfully.

2.2.3.2.3. Data needs and the associated characterization strategies and DQOs developed during Phases III and IV may be different for various phases of an investigation. For example, the data needs and DQOs for collecting geophysical data to traverse and detect concentrated munitions use areas (CMUAs) are significantly different from those for characterizing the amount of UXO within a non-concentrated munitions use area (NCMUA).

2.2.3.2.3.1. Example elements of data needs for finding and characterizing CMUAs include, but are not limited to:

- investigation area;
- percentage of coverage;
- transect spacing;
- anomaly selection criteria; and
- equipment capabilities / validation process.

2.2.3.2.3.2. Example data needs for characterizing NCMUAs include, but are not limited to:

- investigation area;
- amount of coverage;
- UXO density for which the PDT would like to evaluate;

- confidence level for the UXO density estimate;

- tolerable limits on acceptable error;

- anomaly selection criteria; and

- equipment capabilities / validation process.

2.2.3.2.4. Data needs for finding and characterizing MC center on but are not limited to:

- defining sampling units and decision units;

- determining appropriate sampling units, decision units, and sampling density appropriate for the end use of the data (e.g., finding the extent of contamination; exposure units for risk assessment);

- MC analytes attributable to MEC;

- determination of site mean background concentrations; and

- field QC sampling to determine uncertainty and confidence levels in estimates of MC concentrations over sampled areas.

2.2.3.3. Phase III – Develop Data Collection Options.

2.2.3.3.1. Phase III of the TPP process is designed for planning sampling and analysis approaches that will satisfy the data needs identified during Phase II. As described in EM 200-1-2 an optimal sampling strategy will address data needs for both current and future executable phases, such as both the RI and the FS. The PDT should record the appropriate sampling and analysis methods and the data collection options using the worksheets provided in Appendix F of EM 200-1-2 and use those to develop sampling and analysis planning worksheets in the UFP-QAPP.

2.2.3.3.2. During TPP Phase III, the PDT develops the site characterization data collection options. Typical data collections for MR projects include:

- historical documents (including Preliminary Assessment [PA], Historical Records Review [HRR], Archive Search Report [ASR], SI);

- interviews;

- aerial photograph and/or LIDAR analysis (see ESTCP - Nelson et. al, 2008);

- statistical software tools, such as Visual Sample Plan (VSP) and UXO Estimator (see Section 8.3 for further guidance on the use of these statistical tools);

- field investigation techniques, such as geophysical surveys and intrusive investigation (see Chapter 6 for more details); and

- sampling and analysis strategies to characterize MC.

2.2.3.4. Phase IV – Finalize Data Collection Program.

2.2.3.4.1. The final phase in the TPP process is to finalize and document the selected data collection options. This process involves the development of site-specific statements that describe the intended data use(s), the data need requirements, and the means to achieve them. DQO steps documented as a result of the TPP process should be comprehensive and include each of the following data quality requirements.

- Intended Data Use(s):

    - Project objective(s) satisfied.

- Data Need Requirements:

    - Data use (i.e., risk/hazard, compliance, remedy, or responsibility) satisfied;

    - Contaminant, physical hazard, or characteristic of interest identified;

    - Media of interest or location of MEC (e.g., sediment; surface or subsurface soil) identified;

    - Required areas for investigation and depths identified;

    - Required amount of investigation (e.g., fixed or dynamic estimate of the number of samples for HTRW sites, or acres of grids/transects and number of anomalies excavated for MRSs); and

    - Reference concentration of interest or other performance criteria (e.g., action level, compliance standard, decision level, design tolerance for HTRW sites, and confidence level, MEC density for MRSs) identified.

- Appropriate Sampling and Analysis Methods:

    - Sampling method (e.g., discrete, composite or multi-increment sample; sampling equipment and technique; quality assurance/quality control samples; geophysical equipment and data collection; transects or grids; intrusive anomaly investigation) identified; and

    - Analytical method (e.g., sample preparation, laboratory analysis method detection limit and quantitation limit, laboratory quality assurance/quality control) identified.

2.2.3.4.2. See EM 200-1-2 and EPA 2006a for more details regarding development of DQO inputs associated with each of the DQO seven steps. Example DQO inputs include, but are not limited to:

- MEC: Digital geophysical mapping (DGM) transects designed in VSP will ensure an x% confidence level of traversing and detecting a target area with a circular radius of z feet.

- MEC: Random grid approach developed in UXO Estimator will ensure a y% confidence level that there are less than x UXO per acre within the buffer area outside of the target area. Collect sufficient transect data to bound all concentrated munitions use areas (CMUAs) (i.e., target areas).

- MEC: Ensure all QC checks are within performance metrics or measurement quality objectives (MQOs).

- MEC, post remediation sampling: The decision document for MRS Alpha concluded that a potential explosive safety hazard to human receptors exists due to the past history of military munitions training. The RAOs required clearance to a depth of 2 feet below ground surface to current and future use of the property, which includes intrusive activities to a depth of 2 feet below ground surface.

- MC: Ensure laboratory quantitation limits for the selected methods and analytes are below the selected screening criteria (e.g., background levels, risk-based concentrations, action levels).

- MC: Statistically based sampling design will ensure uncertainty can be evaluated for estimates of site-specific mean background concentrations and for concentrations over appropriate exposure areas for risk-based decisions.

- MC: Collect sufficient number of samples to estimate 95% upper confidence of the mean concentrations of chemicals of potential concern to conduct a baseline human health risk assessment (HHRA) and an ecological risk assessment (ERA).

- MC: There is a small arms range backstop at MRS Bravo and visual evidence of lead bullets. The property is scheduled for redevelopment as an industrial park, mean concentrations of lead in the backstop soils will be characterized in a baseline risk assessment using the adult lead model.

- MC: Data will be used to determine whether there is a potential risk to humans that may live at the MRS. MC data from samples collected in the top 10 feet of soil will be used in the BRA.

- MC: The goal of this project is to characterize the soil near CWM items that are identified and removed to determine whether there is a potential risk to humans that may live at the MRS. Soil samples will be collected and analyzed for chemical agents (CA), associated agent breakdown products (ABPs); the data will be used for waste disposal characterization, and if required, will be used in the BRA.

2.2.3.4.3. When data collection is complete, the DQOs will be evaluated to assure that the data needs and, consequently, the related project objectives have been met. Documentation of DQOs will ensure efficient project execution and attainment of project property-closeout or phase completion in a timely fashion with minimal rework. DQOs are relevant to all aspects of the work performed on a project property. There are DQOs for location surveying and mapping (see Chapter 5), geospatial data systems (see Chapter 5), geophysical investigations (see Chapter 8), MC sampling (see Chapter 8), and risk and hazard assessment (see Chapter 12). A completed UFP-QAPP can be an outcome of the TPP. See Appendix E in EM 200-1-2 for a cross walk between the TPP process and the UFP-QAPP.

2.3. Safety.

2.3.1. Protection of the worker and the community from safety and health hazards is a critical component of all USACE activities and operations. The occupational health requirements for USACE are listed in ER 385-1-40. In certain instances where munitions constituents (other than MEC) are involved, ER 385-1-92 may also apply.

2.3.2. Refer to EM 385-1-1 for general safety and health requirements and to ER 385-1-95 and EM 385-1-97 for specific explosives safety requirements. In addition, all USACE MR projects must comply with DoD and Department of the Army (DA) explosives safety regulations and standards, such as DoD 6055.09-M and DA Pam 385-64. The staff within the EM CX also may be contacted for assistance.

2.3.3. An Ordnance and Explosives Safety Specialist (OESS) should be involved during the planning and execution of all MEC or MC related munitions response projects.

2.4. Sustainability.

2.4.1. EO 13423 (Strengthening Federal Environmental, Energy, and Transportation Management) requires the head of each federal agency to improve energy efficiency and reduce greenhouse gas emissions. EO 13514 (Federal Leadership in Environmental, Energy, and Economic Performance) expands on the energy reduction and environmental performance requirements in EO 13423.

2.4.2. In compliance with EO 13423, the DoD outlined its approach to green and sustainable remediation in the Defense Environmental Restoration Program (DERP) Management manual (DoDM 4715.20, March 2012) (http://www.dtic.mil/whs/directives/corres/pdf/471520m.pdf). The Army's Environmental Cleanup Strategic Plan sets forth the Army's approach to green remediation, which seeks to preserve natural resources, minimize energy use, minimize carbon dioxide emissions, maximize recycling and reuse of materials, and minimize the Army's environmental footprint. (http://www.aec.army.mil/usaec/cleanup). The approach encourages PMs to seek opportunities to incorporate options for minimizing the impact on the environment of cleanup actions undertaken at Army installations. The Army's goal is to consider and implement green and sustainable remediation opportunities when and where they make sense. Refer to the EM CX Web page for the latest guidance on green and sustainable practices related to environmental remediation projects (http://www.environmental.usace.army.mil/).

# CHAPTER 3

## Site Visits

3.1. Introduction.

3.1.1. Site visits are made to gather information on the conditions of the project property and to help make informed decisions about project requirements and project technical approach. This chapter describes the elements that will be addressed when planning and conducting the following types of site visits: 1) by the government as part of developing project requirements during the pre-bid process; 2) by contractors when performing due diligence during the bid process; and 3) by the PDT when preparing project planning documents, such as the PMP and UFP-QAPP, after the project begins.

3.1.2. All site visits will follow the provisions of an Abbreviated Accident Prevention Plan (AAPP). During site visits at sites with known or suspected MEC, Explosive Ordnance Disposal [EOD] or UXO personnel must be present so that contact with any potential surface MEC and any subsurface anomalies is prevented using anomaly avoidance techniques. The AAPP will be completed based on the format outlined in EM 385-1-97 for non-intrusive activities. See also EM 385-1-1. The AAPP is for performing non-intrusive activities on potential MMRP sites (e.g., during site visits) before the Accident Prevention Plan (APP) is approved as an appendix to the UFP-QAPP.

3.2. Government Site Visits during Project Requirements Development.

3.2.1. Objectives. The government will consider the following objectives when planning and executing a site visit to develop project requirements:

a. Identify specific elements that should be addressed in the scope of work (SOW) for contract award.

b. Identify and review existing information on past activities at the project property, including site-specific reports, aerial photographs, maps, and geospatial data systems information. All or part of this information should be provided to contractors in advance of their pre-bid site visit.

c. Coordinate with local and/or state entities to discuss data sharing if data gaps have been identified.

d. Determine the actions required to assist project execution at the project property.

e. Identify factors that could influence the cost estimate and project schedule.

3.2.2. Site Visit Attendees. The USACE PM will ensure that the appropriate organizations are represented at the site visit so that complete project requirements can be prepared. The site visit will not be conducted with less than two people. The primary USACE attendees for the site visit may include, but are not limited to:

a. USACE PM;

b. installation PM;

c. MMDC representative(s);

d. project engineer(s);

e. geologist;

f. geophysicist;

g. chemist;

h. GIS specialist;

i. cost estimator; and

j. OE Safety Specialist (OESS) or qualified UXO Safety Officer (UXOSO) (required to accompany the site visit team whenever MEC safety hazards are known or suspected). A Certificate of Risk Acceptance could be processed if the USACE PM wishes to reduce this number for a given project IAW DA Pamphlet (PAM) 385-30.

3.2.3. Rights of Entry. As applicable, the USACE PM is responsible for contacting the property owner/operator to determine the need for and arrange for the preparation of an ROE agreement.

3.2.4. Safety. Two people must be qualified to administer first aid and cardiopulmonary resuscitation (CPR) when conditions set forth in EM 385-1-1 are present.

3.2.5. Information Collection. Site-specific information is reviewed and collected, as required, during the site visit to help the government prepare project requirements and to aid contractors in their proposal development. The USACE PM will collect previous investigation reports and data during the site visit with the intent of using this information to develop project requirements.

3.2.6. Information Sources. The PM should collect and review all sources of project property data that are available, such as, but not limited to:

a. previous MMRP investigation reports (i.e., PA Report, , HRR/ASR, SI Report, RI Report, EE/CA Report, and RA Report);

b. data from databases of record;

c. historical aerial photographic analyses;

d. GIS data from previous district contractors that have worked on the project property (e.g., locations of previous investigations, MEC finds, site boundaries);

e. Global Positioning System (GPS) data for MR area (MRA) and MRS boundaries; and

f. other relevant reports on HTRW projects.

3.2.7. Types of Information. The government will collect and disseminate to contractors the available information needed for contractors to prepare their proposal and technical approach for meeting project requirements and to develop a cost estimate. Potential information to be gathered by the government includes, but is not limited to:

a. project property topography, soil type, and vegetation;

b. preliminary identification of environmental concerns and environmental resources data (e.g., wetlands, endangered species, archaeological, cultural resources, known chemical contamination) ;

c. accessibility to the project property;

d. utility locations;

e. current and future land use;

f. potential locations for staging areas, offices, etc.;

g. clear distances to inhabited buildings;

h. potential concerns with coordination with local police / sheriff / military police to assess security and fencing requirements for explosives storage magazines;

i. locations of support zone and explosives storage magazines;

j. locations of any potential MC sampling areas (targets, firing lines, etc.);

k. locations of any potential MC background/reference samples;

l. logistical coordination for lodging, equipment and vehicle rental, office space, explosives dealers, etc.;

m. coordination with Range Control, Defense Reutilization Management Office, Ammunition Supply Point, and Post Provost Marshall, if applicable; and

n. digital pictures and GPS survey points or project property maps that will be included in the SOW for clarification. This information is valuable for both the government and contractor prior to SOW writing and proposal development and helps document some of the information collected.

3.3. Pre-Bid Contractor Site Visits.

3.3.1. Objectives. Contractors should strive to conduct the site visit so that they collect sufficient information to make an independent assessment of the site characteristics and cost drivers when preparing proposals. The contractor must conduct an independent inspection of the site and gather the information necessary to understand the conditions they will encounter during execution of the work. The site visit will be conducted IAW the safety requirements described in EM 385-1-97.

3.3.2. Site Visit Attendees. The personnel who conduct the due diligence site visit should be qualified to provide an independent assessment of site conditions as one element of due diligence.

3.3.2.1. A USACE representative will accompany contractor representatives performing site visits, unless otherwise specified by the USACE representative leading the site visit.

3.3.2.2. Contractors should not conduct their site visit with less than two contractor staff (not required to be from the same company), unless the site visit is strictly a windshield tour.

a. One person must meet the definition of UXO Qualified Personnel (Ref. DDESB Technical Paper 18) and be experienced in UXO avoidance procedures

b. Two people must be qualified to administer first aid and CPR when conditions set forth in EM 385-1-1 are present.

3.3.3. ROE. As applicable, the USACE PM is responsible for contacting the property owner/operator to determine the need for and arrange for the preparation of an ROE agreement.

3.3.4. AAPP. Because site visits are conducted in anomaly avoidance mode, an AAPP is sufficient for site visits, when required. EM 385-1-1 discusses the AAPP in further detail. See also EM 385-1-97.

3.3.5. Training. Anyone walking or visiting an area of the site that has uncontrolled or unknown hazardous waste is required to have training as required by CFR 1910.120. At a minimum there should be site training on typical site hazards and emergency response.

3.3.6. Information Collection. During the site visit, the contractor performs due diligence to ensure that the information required to prepare a complete and responsive proposal is gathered and that they have obtained the information necessary to fully understand the conditions that they will encounter during project execution. Potential information to be gathered during the site visit depends on the type of work to be performed (e.g., RI, RA) and may include, but is not limited to:

a. identification of features related to munitions use;

b. soil conditions, including presence or absence of interfering rock types (e.g., ferrous rocks);

c. types and density of vegetation;

d. locations of surface water features, including streams, impoundments, and wetlands;

e. locations of buildings and obstacles, including fences;

f. coverage and locations of paved areas;

g. locations of aboveground and belowground utilities;

h. presence and locations of threatened or endangered species;

i. presence and locations of cultural resource areas; and

j. any other information required to meet the contractor's due diligence requirements.

3.4. Project Delivery Team Site Visits.

3.4.1. Contractors may require additional, post-contract award site reconnaissance visits to collect additional site-specific information and/or to engage project stakeholders before and during development of project planning documents. For cost effectiveness and convenience, a site visit may take place at the beginning of a project during the TPP process. This allows the PDT to meet with local leaders (e.g., stakeholders, government representatives, regulators), obtain relevant information, and then visit the project property, possibly being accompanied by local leaders and/or citizens. To enhance the effectiveness of the first TPP meeting, the PDT should engage government leaders, including regulators, in advance of the meeting to provide background information about the project.

3.4.2. The OESS or UXOSO should not have responsibility for more than eight other team members. If more support is needed, an additional team should be established that would be supervised by another OESS or UXOSO. Where there is more than one team, a supervisory OESS or UXOSO should be designated.

3.4.3. Two people must be qualified to administer first aid and CPR when conditions set forth in EM 385-1-1 are present.

# CHAPTER 4

## Project Planning Documents

4.1. Introduction.

4.1.1. This chapter presents guidance to the PDT for preparing key project planning documents.

4.1.2. The project planning documents described within this chapter may not be applicable to all MR projects. The PDT should determine which of the project planning documents are required. Data Item Descriptions (DIDs) outlining project planning document requirements may be contained within contract documents. Where conflicts exist between these DIDs and any other guidance document or requirements (including those contained herein), the DIDs within the contract document take precedence.

4.1.3. The following sections of this manual address planning documents:

a. PMP (Section 4.2)

b. Quality Assurance Surveillance Plan (QASP) (Section 4.3)

c. UFP-QAPP (Section 4.4)

d. Accident Prevention Plan/Site Safety and Health Plan (APP/SSHP) (Section 4.5)

e. Property Management Plan (Section 4.6)

f. Environmental Protection Plan (EPP) (Section 4.7)

g. Interim Holding Facility (IHF) Siting Plan / Physical Security Plan (PSP) (Section 4.8)

h. Waste Management Plan (WMP) (Section 4.9)

i. Explosives Management Plan (Section 4.10)

j. Munitions Response Safety submissions and Site Plans(Section 4.11)

k. Community Relations Plan (CRP) (Section 4.12)

4.2. Project Management Plan.

4.2.1. ER 5-1-11 requires every project to have a PMP.

4.2.2. A PMP is a formal, approved, living document used to define requirements and expected outcomes and guide project execution and control. Primary uses of the PMP are to facilitate communications among participants, assign responsibilities, define assumptions, and document decisions to establish baseline plans for scope, cost, schedule and quality objectives against which performance can be measured, and to adjust these plans as actual dictate. The PMP is developed by the project delivery team (PDT) (ER 5-1-11).

4.2.3. The USACE PM, with input from the PDT should prepare a PMP IAW the requirements of Project Delivery Process PROC 02000, PMP Development, which is available to USACE staff on the Quality Management System (QMS) Web site. The QMS was established under ER 5-1-14 and is a formalized system that defines the structure, authority, responsibilities, resources, planning, and documented procedures needed to implement USACE's quality policy. The following subsections identify the key sections of the USACE PMP. Individual processes are identified within PROC 02000 for developing each section.

4.3. Quality Assurance Surveillance Plan.

4.3.1. Purpose and Overview.

4.3.1.1. This section describes the roles and responsibilities of the USACE PDT with regard to development and implementation of the project-specific QASP. A QASP that directly corresponds to a contract's specified performance standards is used to measure contractor performance and to ensure that the government receives the quality of services called for under the contract and pays only for the acceptable levels of services received. Each USACE PDT member has an important part to play to ensure quality products are received from the contractor.

4.3.1.2. Effective QA is comprehensive (i.e., it involves all aspects of the entire life cycle of projects) and:

a. ensures people accomplish appropriate tasks at the appropriate time;

b. ensures customer objectives and expectations are met or exceeded;

c. includes the use of a multidisciplinary team of trained personnel;

d. includes using a comprehensive and systematic approach to project planning (e.g., TPP);

e. includes reviewing project documents and project status; and

f. includes observing field operations.

4.3.2. Responsibilities.

4.3.2.1. Site PM.

a. Oversees the development and implementation of the QASP.

b. Specific surveillance activities for PMs will vary depending upon the type of project. Common responsibilities for projects are provided in the QASP template provided in Appendix B.

4.3.2.2. PDT.

a. Provides technical input to the PM for information to be included in the QASP.

b. Implements the project-specific QASP. Specific QASP responsibilities for the PDT team members will vary depending upon the type of project. Common responsibilities for various PDT members also are provided in the QASP template provided in Appendix B.

c. Provides the KO any specifications for inspection, testing, and other contract quality requirements essential to ensure the integrity of the product or service. For service contracts, like most MMRP contracts, these quality requirements are documented in a QASP.

4.3.3. QASP Overview.

4.3.3.1. All service contracts require the development and implementation of a QASP. A QASP describes how government personnel will evaluate and assess contractor performance. The purpose of the QASP is to describe how project performance will be measured and assessed against performance standards. It is based on the premise that the contractor is responsible for managing site-specific QC.

4.3.3.2. The QASP is intended to measure performance against the standards in the Performance Work Statement (PWS) or SOW. As such, these interdependent documents must be coordinated. Since the PWS/SOW and QASP are intertwined, it is effective and efficient to write them simultaneously.

4.3.3.3. The QASP is a requirement of Federal Acquisition Regulation (FAR) Part 46.103(a) for service contracts. There are several considerations when developing a QASP.

4.3.3.3.1. The QASP describes the contract technical quality requirements, including inspection and testing requirements.

4.3.3.3.2. Preliminary QASPs should be developed for each project in conjunction with the development of the PWS/SOW. The QASP should be revised and modified to fit site-specific conditions and requirements and the contractor's QC Plan. Effective use of the QASP, in conjunction with the contractor's QC Plan, will allow the government to evaluate the contractor's success in meeting the project objectives. The QASP may be required to be developed by the contractor or may be drafted by the government.

4.3.3.3.3. The entire PDT should meet to discuss the project's objectives and to have input on the final measures contained in the QASP.

4.3.3.3.4. The majority of effort in developing the QASP is tailoring the QASP template to meet project-specific needs.

4.3.3.4. The QASP identifies roles and responsibilities of Army QA personnel; methods for performance assessments and evaluation standards; the surveillance methodology, which includes the Surveillance Activities Table that identifies the work that will be done and how it will be documented; the Evaluation Standards, which identify the possible ratings that can be assigned when assessing how well the contractor's work measures up to the contract requirements for the activities monitored in the Surveillance Activities Table; and the surveillance monitoring documentation, which includes the QA monitoring form, the Corrective Action Request (CAR) form that identifies how the government will communicate non-conformances it observes, and technical QA monitoring forms. A QASP template is provided in Appendix B.

4.3.4. QASP Review Documentation.

4.3.4.1. Various forms may be used to document review activities that can be incorporated as part of the QASP. The review documentation forms that are used should be tailored individually to the project, as circumstances warrant.

4.3.4.2. The following are some examples of commonly used review documentation forms:

a. Generic QA Checklist (see EM-200-1-6);

b. QA Report (see Appendix C for sample discipline-specific QA reports);

c. CAR; and

d. After Action or Final QA Report Content.

4.4. Uniform Federal Policy – Quality Assurance Project Plan.

4.4.1. Overview. The UFP-QAPP integrates all technical and quality aspects for the life cycle of the project, including planning, implementation, and assessment. It documents how QA and QC are applied to an environmental data collection operation to ensure that the results obtained will satisfy the stated performance criteria. Development of a UFP-QAPP is applicable to investigations, remediation activities or remedy solutions, and final cleanup and long-term management/stewardship activities.

4.4.2. Purpose and Available Guidance. The UFP-QAPP format provides project-level guidance for implementing the systematic planning process for environmental sampling. It was developed via collaboration between the USEPA, DoD, and Department of Energy (DOE). The PDT should use the UFP-QAPP format to plan, manage, and monitor all aspects of the MEC and MC components of MR actions. In addition, the UFP-QAPP helps the PDT manage a project's communications and define roles and responsibilities. Guidance on the UFP-QAPP and the UFP-QAPP workbook format can be found at http://www.ert2.org/t2mrportal and http://www.epa.gov/fedfac/documents/qualityassurance.htm. The USEPA Web site also contains an electronic UFP-QAPP workbook, which will facilitate completion of the various worksheets that are part of the project-specific UFP-QAPP. The preferred example for preparing MEC-focused UFP-QAPPs may be found at http://www.ert2.org/T2MRPortal/pages/mrqa.html.

4.4.2.1. The UFP-QAPP Manual is a key guidance document for preparing UFP-QAPPs. The UFP-QAPP Manual (Part 1 of a comprehensive set of guidance documents contained on the

USEPA Web site provided in Section 4.4.2) is not program specific and is intended to be as comprehensive as possible. Project teams are encouraged to use a graded approach when developing QAPPs, giving appropriate consideration to the significance of the environmental problems to be investigated, the types of environmental decisions to be made, the impact on human health and the environment, and available resources. This graded approach may result in not all of the worksheets needing to be used, but only those that are relevant to the project.

4.4.2.2. To assist in compiling critical UFP-QAPP information, several additional guidance manuals are available on the USEPA Web site, including Part 2A, the UFP-QAPP Workbook, which provides blank worksheets; Part 2B, the UFP-QAPP Compendium, which outlines QA/QC activities that should be included in a UFP-QAPP for all CERCLA projects; and Part 2C, Example QAPPs, which provides examples of completed worksheets and shows how to fulfill the requirements of the UFP-QAPP Manual.

4.4.3. UFP-QAPP Worksheet Development. The worksheets address all requirements of CIO 2106-G-05 (USEPA Guidance on Quality Assurance Project Plans). Users are free to modify the worksheets as necessary to suit project-specific requirements; however, all elements required by CIO 2106-G-05 must be addressed, or a satisfactory explanation must be provided for their exclusion. Selected UFP-QAPP worksheets can be taken to project scoping sessions (e.g., worksheets for the CSM, DQOs, Project Tasks and Schedule, Sampling Design and Rationale) and completed during the project planning stage. Some of the information used for these worksheets also may be applicable to the worksheets completed during the TPP process (see EM 200-1-2). Subsequently, the worksheet information can be presented in tabular format in the UFP-QAPP. The worksheets are designed to ensure consistent content and presentation of information in a project-specific UFP-QAPP. If the QAPP worksheets are not used, information required by the worksheets still must be presented in the UFP-QAPP, as appropriate to the project.

4.4.4. Use of Standard Operating Procedures (SOPs). To simplify UFP-QAPP preparation, written SOPs should be included as an appendix. If procedures are documented in a separate document, that document should be cross-referenced and either attached for review and approval (if not already approved) or referenced with sufficient specificity that they can be found easily. SOPs should be reviewed so that they are applicable to site-specific conditions, and any variances to the SOP need to be documented. The PDT should develop SOPs for each definable feature of work. The following are the recommended minimum SOPs that should be included:

a. Anomaly avoidance;

b. Brush clearance;

c. Civil surveying;

d. Geospatial data management;

e. Geophysical data collection (digital and analog);

f. DGM data processing and interpretation, if needed;

g. Target reacquisition, if needed;

h. Intrusive operations;

i. Explosives management;

j. Geophysical QC;

k. MPPEH disposition;

l. Demolition operation;

m. MC sample collection procedures;

n. Hazardous material shipping, if needed (applies to certain MC samples, x-ray fluorescence [XRF] sources, EXPRAY™ kits, etc.);

o. Chemistry data management;

p. MC data review; and

q. Analytical laboratory SOPs.

4.4.5. UFP-QAPP Elements. There are four elements of a UFP-QAPP: Project Management and Objectives, Measurement and Data Acquisition, Assessment and Oversight, and Data Review. Table 2 in the UFP-QAPP Manual shows the sections of the UFP-QAPP required for each element. Table 4-1 shows the worksheet numbers and titles and a crosswalk with the sections in the CIO 2106-G-05 guidance. This table also provides general guidance on the applicability of the worksheets to MC and MEC projects and the section in this manual with information that may be helpful when filling out a worksheet. When developed for a project site where both MEC and MC are concerns, a single UFP-QAPP may be prepared. Many worksheets are applicable to both, while other worksheets may need to be divided into sections for the MEC and MC components of the project.

Table 4-1: UFP- QAPP Worksheets

| Worksheet Number(s) | Worksheet Title | CIO 2106-G-05 QAPP Guidance Section[a] | | Potential Applicability | | EM 200-1-15 Section |
|---|---|---|---|---|---|---|
| | | Section | Title | MEC | MC | |
| 1, 2 | Title and Approval Page | 2.2.1 | Title, Version, and Approval/Sign-Off | ● | ● | NA |
| 3, 5 | Project Organization and QAPP Distribution | 2.2.3 | Distribution List | ● | ● | 2.1; 2.2 |
| | | 2.2.4 | Project Organization and Schedule | | | |
| 4, 7, 8 | Personnel Qualifications and Sign-off Sheet | 2.2.1 | Title, Version, and Approval/Sign-Off | ● | ● | 2.1.4; 6.2.1, 8.2.5.1 |
| | | 2.2.7 | Special Training Requirements and | | | |

| Worksheet Number(s) | Worksheet Title | CIO 2106-G-05 QAPP Guidance Section[a] | | Potential Applicability | | EM 200-1-15 Section |
|---|---|---|---|---|---|---|
| | | Section | Title | MEC | MC | |
| | | | Certification | | | |
| 6 | Communication Pathways | 2.2.4 | Project Organization and Schedule | ● | ● | 2.1; 2.2 |
| 9 | Project Planning Session Summary | 2.2.5 | Project Background, Overview, and Intended Use of Data | ● | ● | 2.2 |
| 10 | Conceptual Site Model | 2.2.5 | Project Background, Overview, and Intended Use of Data | ● | ● | 2.2.3.1, 12.2 |
| 11 | Project Data Quality Objectives | 2.2.6 | Data/Project Quality Objectives and Measurement Performance Criteria | ● | ● | 2.2.3.2; 5.3; 9.2; 11.3 |
| 12 | Measurement Performance Criteria | 2.2.6 | Data/Project Quality Objectives and Measurement Performance Criteria | ● | ● | 5.3.7; 11.3; Tables 11-3 through 11-6 |
| 13 | Secondary Data Uses and Limitations Table | Chapter 3 | QAPP Elements for Evaluating Existing Data | ● | ● | NA |
| 14, 16 | Project Tasks and Schedule | 2.2.4 | Project Organization and Schedule | ● | ● | 2.1; 2.2 |
| 15 | Project Action Limits and Laboratory-Specific Detection / Quantitation Limits | 2.2.6 | Data/Project Quality Objectives and Measurement Performance Criteria | | ● | 7; 8.2.4.6; 8.2.6.9 |
| 17 | Sampling Design and Rationale | 2.3.1 | Sample Collection Procedure, Experimental Design, and Sampling Tasks | ● | ● | 8.2.4; 8.3.2; 8.5; 8.6; 8.7 |
| 18 | Sampling Locations and Methods | 2.3.1 | Sample Collection Procedure, Experimental Design, and Sampling Tasks | ● | ● | 8.8 |
| | | 2.3.2 | Sampling Procedures and Requirements | | | |
| 19, 30 | Sample Containers, Preservation, and Hold Times | 2.3.2 | Sampling Procedures and Requirements | | ● | 7.5.4; 7.5.5; 7.5.6; 7.6.9; 7.7.3; 7.8.9 |
| 20 | Field QC | 2.3.5 | Quality Control Requirements | ● | ● | 11 |
| 21 | Field SOPs | 2.3.2 | Sampling Procedures and Requirements | ● | ● | 4.4.4; 8.8.1-8.8.4 |
| 22[b] | Field Equipment Calibration, Maintenance, Testing, and | 2.3.6 | Instrument/Equipment Testing, Calibration and Maintenance Requirements, Supplies and Consumables | ● | ● | 6.7.2; 7 |

| Worksheet Number(s) | Worksheet Title | CIO 2106-G-05 QAPP Guidance Section[a] | | Potential Applicability | | EM 200-1-15 Section |
|---|---|---|---|---|---|---|
| | | Section | Title | MEC | MC | |
| | Inspection | | | | | |
| 23 | Analytical SOPs | 2.3.4 | Analytical Methods Requirements and Task Description | ● | ● | 7.5.4; 7.5.5; 7.5.6; 7.6.9; 7.7.3; 7.8.9 |
| 24[b] | Analytical Instrument Calibration | 2.3.6 | Instrument/Equipment Testing, Calibration and Maintenance Requirements, Supplies and Consumables | ● | ● | 7 |
| 25[b] | Analytical Instrument and Equipment Maintenance, Testing, and Inspection | 2.3.6 | Instrument/Equipment Testing, Calibration and Maintenance Requirements, Supplies and Consumables | ● | ● | NA |
| 26, 27 | Sample Handling, Custody, and Disposal | 2.3.3 | Sample Handling, Custody Procedures, and Documentation | | ● | NA |
| 28 | Analytical Quality Control and Corrective Action | 2.3.5 | Analytical Quality Control and Corrective Action | ● | ● | 11 |
| 29 | Project Documents and Records | 2.3.8 | Documentation and Records Requirements | ● | ● | 13 |
| 31, 32, 33 | Assessments and Corrective Action | 2.4 | Assessments and Data Review (Check) | ● | ● | 4.3, Appendix B |
| | | 2.5.5 | Reports to Management | | | |
| 34 | Data Verification and Validation Inputs | 2.5.1 | Data Verification and Validation Targets and Methods | ● | ● | 8.2.4.7; 8.8.8 |
| 35 | Data Verification Procedures | 2.5.1 | Data Verification and Validation Targets and Methods | ● | ● | 8.2.4.7; 8.8.8 |
| 36 | Data Validation Procedures | 2.5.1 | Data Verification and Validation Targets and Methods | ● | ● | 8.8.8 |
| 37 | Data Usability Assessment | 2.5.2 | Quantitative and Qualitative Evaluations of Usability | ● | ● | 8.8.8 |
| | | 2.5.3 | Potential Limitations on Data Interpretation | | | |
| | | 2.5.4 | Reconciliation with Project Requirements | | | |

a See http://www.epa.gov/oeitribalcoordination/2106-G-05%20QAPP%20Final%20Draft%2001-17-12.pdf.

b These worksheets may be combined into one worksheet for geophysics components of MR projects in order to document testing and maintenance of geophysical equipment.

4.4.5.1. Project Management and Objectives Elements. The project management and objectives elements of a UFP-QAPP ensure that the project has a defined purpose by documenting the environmental problem, the environmental questions being asked, and the environmental decisions that need to be made. The elements in this part of the UFP-QAPP identify the project quality objectives necessary to answer those questions and support those environmental decisions. They also address project management considerations, such as roles and responsibilities. The PDT also should consider including a narrative at the beginning of the UFP-QAPP that includes a brief description of the project's purpose and scope, the authority for performing the work (including descriptions of the various government organizations that are involved and their responsibilities), and background information on the installation (if applicable) and project site(s), including a historical overview.

4.4.5.2. Measurement and Data Acquisition Element. This UFP-QAPP element group covers how project data will be collected, measured, and documented. Proper implementation of these activities helps ensure that resulting data are scientifically sound, of known and documented quality, and suitable for their intended use. The worksheets associated with this element address the QC activities that will be performed during each phase of data collection and generation, from sampling to data reporting, evaluating QC acceptance limits and the performance of corrective actions for nonconformances.

4.4.5.3. Assessment and Oversight Element. This UFP-QAPP element ensures that planned project activities are implemented as described in the UFP-QAPP and that reports are provided to apprise management of the project status and any QA issues that arise during implementation. Assessment activities help to ensure that the resultant data quality is adequate for its intended use and that appropriate responses are in place to address nonconformances and deviations from the UFP-QAPP. Frequently, project personnel identify deviations from the UFP-QAPP without the benefit of formal, scheduled assessments. This element also addresses those situations and describes the process by which the need for corrective action is documented, reported, and implemented and its effectiveness assessed.

4.4.5.4. Data Review Element. Data review is the process by which data are examined and evaluated to varying levels of detail and specificity by a variety of personnel who have different responsibilities within the data management process. It includes verification, validation, and usability assessments. This UFP-QAPP element encompasses the data review activities used to ensure that only scientifically sound data of known and documented quality are collected to meet project quality objectives. The approach used for data review of a project must be appropriate to the project requirements. Although data review takes place after the data have been generated, determination of the type of data review that is required to meet quality objectives begins during the planning phase of the project.

4.4.5.5. Appendices. The following is a listing of the possible appendices to the UFP-QAPP, depending on the specific project needs, and the sections in this manual where they are discussed. Appendices that are not required for a specific project should be noted.

a. APP (see Section 4.5);

b. Property Management Plan (see Section 4.6);

c. EPP (see Section 4.7);

d. IHF Siting Plan (for CWM projects) (see Section 4.8);

e. WMP (see Section 4.9);

f. Explosives Management Plan (see Section 4.10);

g. Munitions Response Safety Submissions and Site Plans (see Section 4.11); and

h. CRP (see Section 4.12).

4.4.6. UFP-QAPP Implementation. After field activities begin, any deviation from the specified requirements or procedures contained in the UFP-QAPP should be documented in a written document, such as a non-conformance report, and distributed as appropriate.

4.5. Accident Prevention Plan/Site Safety and Health Plan (APP/SSHP).

4.5.1. An APP is prepared as part of the safety and health policy program. The APP/SSHP must interface with the executing organization's existing overall safety and health program. The APP must be prepared in the format shown and address all the elements in EM 385-1-1. Where a specific element is not applicable, the element should be listed in the plan and a statement included that the element is not applicable with a brief justification for its omission. The APP/SSHP is an implementing document with emphasis on who will have each of the specific responsibilities and how and when each of the applicable requirements will be performed. If applicable, the prime contractor shall integrate all subcontractor work activities into the APP/SSHP, make the APP/SSHP available to all contractor and subcontractor employees, and ensure that all subcontractors integrate provisions of the APP/SSHP in their work activities.

4.5.2. A key component of the APP is a detailed activity hazard analysis (AHA), which should provide a detailed analysis of the hazards for each task involved in the fieldwork, as well as the procedures to be employed to eliminate or minimize those hazards. Hazards and mitigation methods should be identified for each component of a particular task. For example, hazards for an intrusive investigation could include meteorological extremes (e.g., wind, precipitation, lightning), biological hazards (e.g., ticks, snakes), physical hazards (e.g., slip/trip/fall, lifting heavy munitions debris [MD]), explosives hazards, and radiological hazards (e.g., depleted uranium, XRF sources). Each hazard and its corresponding procedures for hazard mitigation should be identified for each task. For MR projects, the key components that should be analyzed in the AHA include, but are not limited to, the following (as applicable to the project):

a. surface clearance;

b. surveying;

c. vegetation removal;

d. geophysical survey;

e. target reacquisition;

f. intrusive operations;

g. airborne operations;

h. water investigation tasks (e.g., geophysical survey, reacquisition, anomaly investigation, sediment sampling);

i. MEC demolition operations;

j. MPPEH handling;

k. radiation screening;

l. surface soil sampling;

m. subsurface soil sampling;

n. surface water sampling;

o. sediment sampling;

p. drilling; and

q. groundwater sampling.

4.5.3. After the APP has been approved, it is critical that all employees involved in the project read and understand the hazards associated with the project and the procedures that each employee is to perform to mitigate those hazards.

4.5.4. If new hazards are identified during the MR project, the PDT should update the APP to develop mitigation methods for those hazards and ensure the safety of the field team members.

4.5.5. The following information, in addition to that specified in EM 385-1-1, is required for APPs prepared for MEC and RWCM projects.

4.5.5.1. <u>Background Information</u>. List the phases of work and hazardous activities requiring an AHA.

4.5.5.2. <u>Subcontractors and Suppliers</u>. Provide the means for controlling and coordinating subcontractors and suppliers.

4.5.5.3. <u>Safety and Health</u>. Include a section on safety and health expectations, incentive programs, and compliance. The contractor must provide the following:

a. The company's written safety program goals and objectives and accident experience goals for the contract;

b. A brief description of the company's safety incentive programs (if any);

c. Policies and procedures regarding noncompliance with safety requirements (to include disciplinary actions for violation of safety requirements); and

d. Written company procedures for holding managers and supervisors accountable for safety

4.5.5.4. Personal Protective Equipment (PPE). Outline procedures (who, when, how) for conducting HAs and written certifications for use of PPE. Outline procedures to be followed to assure the proper use, selection, and maintenance of personal protective and lifesaving equipment (e.g., protective footwear, protective gloves, hard hats, safety glasses, hearing protection, body harnesses, lanyards).

4.5.5.5. Contractor Information. The contractor shall provide information on how they will meet the requirements of applicable sections of EM 385-1-1in the APP. As a minimum, excavations, scaffolding, medical and first aid requirements, sanitation, PPE, fire prevention, machinery and mechanized equipment, electrical safety, public safety requirements, and chemical, physical agent, and biological occupational exposure prevention requirements shall be addressed, as applicable.

4.5.5.6. Site-Specific Hazards and Controls. Detailed site-specific hazards and controls shall be provided in the AHA for each activity of the operation.

4.5.6. The Contractor shall develop a Site Safety and Health Plan (SSHP) as an attachment to the APP. The SSHP shall address all occupational safety and health hazards associated with the site MEC removal operations. The SSHP shall address the applicable requirements of 29 CFR 1910.120(b) (4) (ii), 29 CFR 1926.65(b) (4) (ii), EM 385-1-1, ER 385-1-95, and any other applicable federal, state, and local safety and health requirements. The level of detail provided shall be tailored to the type of work, complexity of operations to be accomplished, and the hazards anticipated. The SSHP shall address those elements that are specific to the site and have the potential for negative effects on the safety and health of workers. Where a specific element is not applicable, list the element in the plan and state that the element is not applicable with a brief justification for its omission. SSHP elements adequately covered elsewhere in the APP need not be duplicated. When a specific element is repeated, list the element in the plan and state that the element is addressed in the APP.

4.6. Property Management Plan. This plan details procedures for the management of government property IAW FAR Part 45.5 and its supplements.

4.7. Environmental Protection Plan. The EPP details the operational procedures and methods to be implemented to conduct environmental protection, which is the prevention/control of pollution and habitat disruption that may occur to the environment during project execution. The control of environmental pollution and damage requires consideration of land, water, air, and biological and cultural resources and includes management of visual aesthetics; noise; solid, chemical, gaseous, and liquid waste; and radiant energy and radioactive material as well as other pollutants.

4.7.1. On-site project activities conducted under CERCLA are required to meet the substantive requirements of all pertinent federal, state, and territorial environmental laws, regulations, and EOs.

4.7.2. This site-specific plan documents the intent and process to minimize and mitigate environmental pollution and damage that may occur as the result of project operations. The environmental resources within the project boundaries and those affected outside the limits of permanent work must be protected during the entire duration of the project. All parties involved in the project (government personnel and contractors) must comply with all applicable environmental laws and regulations.

4.7.3. The purpose of the EPP is to present a comprehensive overview of known or likely issues that must be addressed during the current phase of project execution. Issues of concern must be defined within the EPP, as outlined in this section. Each topic should be addressed at a level of detail commensurate with the environmental issue and required project task(s). Topics or issues that are not identified in this section, but are considered necessary, must be identified and discussed after those items formally identified in this section.

4.7.4. The following are general requirements for the EPP.

4.7.4.1. Identify the name(s) of the person(s) within the contractor's organization who is (are) responsible for ensuring adherence to the EPP.

4.7.4.2. Identify the name(s) and qualifications of the person(s) responsible for training the contractor's environmental protection personnel.

4.7.4.3. Provide a description of the contractor's environmental protection personnel training program.

4.7.4.4. Provide figure(s) showing locations of proposed temporary excavations or embankments for haul roads, stream crossings, material storage areas, structures, sanitary facilities, and stockpiles of excess or spoil materials, including methods to control runoff and to contain materials on the site. The figure(s) also should indicate access routes. If these are addressed in the UFP-QAPP, a reference to the appropriate figure will suffice.

4.7.4.5. Provide figure(s) showing the proposed activity in each portion of the area and identifying the areas of limited use or nonuse. The figure should include measures for marking the limits of use areas, including methods for protection of features to be preserved within authorized work areas. If these are addressed in the UFP-QAPP, a reference to the appropriate figure will suffice.

4.7.4.6. Identify and provide locations of trees and shrubs to be removed from within the project site.

4.7.4.7. Identify and provide locations of existing waste disposal sites within the project site and identify appropriate off-site facilities for recycling, transport of hazardous waste, and disposal of contaminated wastewater.

4.7.4.8. Include a Spill Control Plan (provide relevant reference to APP.).

4.7.4.9. Include a WMP (see Section 4.9.).

4.7.4.10. Include an Air Monitoring Plan (if applicable, provide relevant reference to APP.).

4.7.4.11. Include an Ecological Resources Plan. Ecological resources planning shall follow the process identified in Figure 4-1. This process begins with gathering readily available site data, which should include any information on threatened and endangered species that are federally or state listed as well as information on critical habitat or other sensitive environments (wetlands, coastal zones, etc.). This information can be gathered from existing documents (e.g., SI Report, an installation Integrated Natural Resource Management Plan), databases (e.g., the U.S. Fish and Wildlife Service and state protected occurrence databases), GIS, phone inquiries, etc. It must be sufficient to complete the Army Checklist for Important Ecological Places (see Figure 4-2).

4.7.4.11.1. If ecological concerns are not present at the site, a letter to the applicable regulatory agencies shall be completed and submitted with site information and the completed checklist (see Section 13.3 for ecological reporting guidance). The conclusion of the letter shall be that additional coordination is not intended with those agencies; however, if the agencies identify ecological concerns that the PDT did not, a meeting to address those concerns should be held.

4.7.4.11.2. If ecological concerns are present at the site, a letter to the applicable regulatory program shall be completed and submitted with site information and the completed checklist. The outcome shall be a meeting with the appropriate agencies to clarify ecological concerns relevant to the project, particularly sensitive receptors, breeding seasons, areas impacted, etc.

4.7.4.11.3. If there are ecological concerns present and the information obtained is insufficient for the PDT to determine that ecological resources can be protected appropriately to prevent a substantive impact, an ecological field survey should be conducted. The ecological field survey shall be confined to the footprint of the area to be disturbed during the work effort and other areas affected by activities conducted within the disturbed area and consist of documenting protected habitats or species that inhabit or utilize the project area. This should include documenting habitat types, limits, and quality. A plan describing the procedures and work areas should be prepared and submitted prior to survey execution. All surveys should be conducted using anomaly avoidance procedures or IAW an ESS.

4.7.4.11.4. After initial coordination with the appropriate regulatory agencies has taken place and the survey is conducted (if necessary), an ecological resources plan shall be prepared to address biological resources and wetlands. This plan shall define procedures for identifying and protecting biological resources and wetlands known to be on the project site and/or identify procedures to be followed if biological resources and wetlands not previously known to be on site or in the area are discovered during project execution. Each species may have different requirements for avoidance, such as a buffer distance, time of year restriction, or active survey while work is being performed. The plan must include methods and SOPs to assure the protection and conservation of known or discovered listed threatened and endangered species and biological resources. It shall be developed to ensure that any action taken is not likely to jeopardize the continued existence of any threatened or endangered species or result in the destruction or adverse modification of designated critical habitat. It shall clearly prohibit any action that results in a “take” of a threatened or endangered species without a determination that any “take” is not likely to jeopardize the continued existence of any threatened or endangered species.

4.7.4.11.5. The plan must identify lines of communication among contractor personnel, USACE personnel, and appropriate agency personnel. Unless specifically authorized and in compliance with procedures in this plan, project personnel may not enter, disturb, destroy, or allow discharge of contaminants into any wetlands. Project personnel must minimize interference with, disturbance to, and damage to fish, wildlife, and plants, including their habitat. The protection of threatened and endangered animal and plant species, including their habitat, is the PDT's responsibility IAW federal, state, regional, and local laws and regulations.

4.7.4.11.6. A qualified biologist or ecologist is required to manage all ecological resource planning efforts and to participate in any field mitigation efforts. At a minimum, a qualified biologist or ecologist is a person with a degree in biology, marine biology, forestry, wildlife biology, ecology, or zoology or closely related field and who has a minimum of 4 years of experience that clearly demonstrates ability and understanding of the fundamental principles and techniques of biological analysis of one or more biological, ecological, marine science, physical science, or natural resources discipline. Depending on site-specific resources, additional qualifications may be required (e.g., focus on marine biology for water MRSs, focus on botany for endangered plant species).

4.7.4.11.7. During biological avoidance, all results and findings shall be documented. Documentation should include specific information about biological resources associated with the MRS, such as species identified, populations, and avoidance efforts (e.g., transects relocated). Documentation also shall include field notes of the site biologist. After consultation with project counsel, all documentation shall be incorporated into the phase-specific report for the project, which is discussed further in Chapter 13.

4.7.4.11.8. The results of the ecological resources survey and biological avoidance activities during project execution shall be reported IAW the procedures described in Section 13.3.

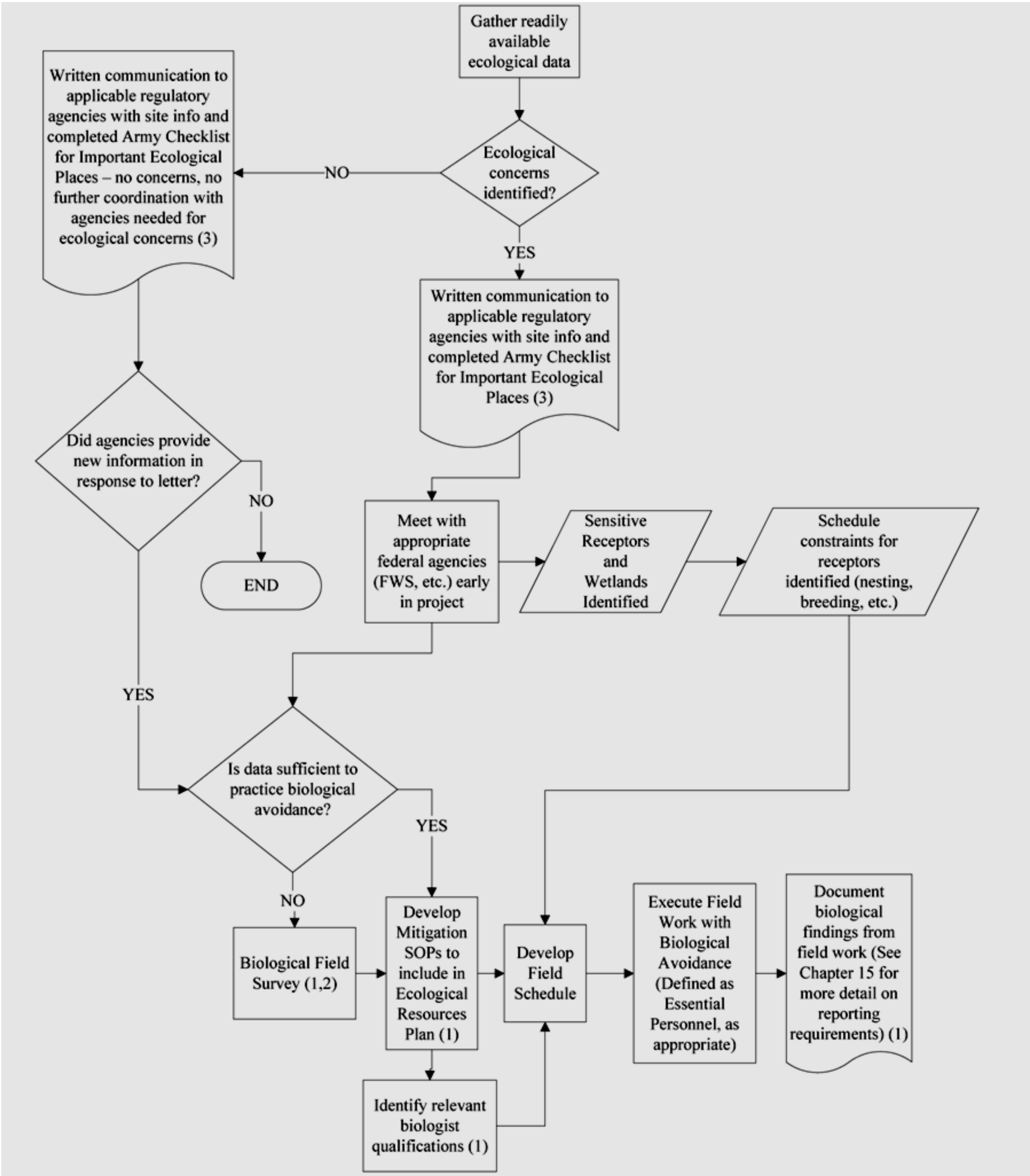


Figure 4-1: Ecological Resources Planning Process

(1) Requires coordination with appropriate agencies
(2) Evaluation can be conducted by the agency, USACE, or under contract.
(3) Required to be submitted into project file and database of record (e.g., FRMD)

| | |
|---|---|
| 1 | Locally important ecological place identified by the Integrated Natural Resource Management Plan, Base Realignment and Closure (BRAC) Cleanup Plan or Redevelopment Plan, or other official land management plans |
| 2 | Critical habitat for federally designated endangered or threatened species |
| 3 | Marine Sanctuary |
| 4 | National Park |
| 5 | Designated Federal Wilderness Area |
| 6 | Sensitive areas identified in Coastal Zone Management Plans created pursuant to the CZMA |
| 7 | Sensitive areas identified under the National Estuary Program or Near Coastal Waters Program |
| 8 | Critical areas identified under the Clean Lakes Program |
| 9 | National Monument |
| 10 | National Seashore Recreational Area |
| 11 | National Lakeshore Recreational Area |
| 12 | Habitat known to be used by federally designated or proposed endangered or threatened species |
| 13 | National Preserve |
| 14 | National or State Wildlife Refuge |
| 15 | Unit of Coastal Barrier Resources System |
| 16 | Coastal Barrier (undeveloped) |
| 17 | Federal land designated for protection of natural ecosystems |
| 18 | Administratively Proposed Federal Wilderness Area |
| 19 | Spawning areas critical for the maintenance of fish/shellfish species within river, lake, or coastal tidal waters |
| 20 | Migratory pathways and feeding areas critical for maintenance of anadromous fish species within river reaches or areas in lakes or coastal tidal waters in which fish spend extended periods of time |
| 21 | Terrestrial areas utilized for breeding by large or dense aggregations of animals |
| 22 | National river reach designated as Recreational |
| 23 | Habitat known to be used by state designated endangered or threatened species |
| 24 | Habitat known to be used by species under review as to its federally endangered or threatened status |
| 25 | Coastal Barrier (partially developed) |
| 26 | Federally designated Scenic or Wild River |
| 27 | State land designated for wildlife or game management |
| 28 | State-designated Scenic or Wild River |
| 29 | State-designated Natural Areas |
| 30 | Particular areas, relatively small in size, important to maintenance of unique biotic communities |
| 31 | State-designated areas for protection or maintenance of aquatic life |
| 32 | Wetlands |
| 33 | Fragile landscapes, land sensitive to degradation if vegetative habitat or cover diminishes |

Figure 4-2: Army Checklist for Important Ecological Places

4.7.4.12. Include a Cultural Resources Plan. Cultural resources planning shall follow the process identified in Figure 4-3.

4.7.4.12.1. The cultural resource planning process begins with gathering readily available site data. The objective of the initial review is to determine the likelihood of cultural resources being present and begins with identifying and reviewing documents on previously identified cultural resources on and near the site. This information can be gathered from existing documents (e.g., SI Report, an installation Integrated Cultural Resource Management Plan), databases, GIS, phone inquiries, etc. It must be sufficient to complete the Checklist for Important Cultural Places (Figure 4-4).

4.7.4.12.2. Any documentation obtained by contractor or USACE personnel that includes actual locations of cultural resource must be marked and maintained as "For Official Use Only" and kept separately from other publicly releasable information. This marking is based on 16 United States Code (U.S.C.) 470w-3(a), Confidentiality of the location of sensitive historic resources. Unless specific written direction is given in contract documents or by Contracting Officer (KO) letter, these locations will only be provided to the relevant contractor personnel, State Historic Preservation Officers (SHPOs)/Tribal Historic Preservation Officers (THPOs), and USACE.

4.7.4.12.3. If cultural concerns are not present at the site, a letter to applicable regulatory agencies shall be completed and submitted with site information and the completed checklist. The conclusion of the letter shall be that additional coordination is not intended with those agencies; however, if the agencies identify cultural concerns that the PDT did not, a meeting to address those concerns should be held.

4.7.4.12.4. If cultural concerns are present at the site, a letter to the applicable regulatory agency shall be completed and submitted with site information and the completed checklist. The outcome shall be a meeting with the appropriate agencies to clarify cultural concerns relevant to the project, particularly areas impacted.

4.7.4.12.5. If cultural resources are present at the site and the information obtained is insufficient for USACE to determine that cultural resources can be protected appropriately to prevent a substantive impact (such as excavation, injury, or destruction of any historic or prehistoric ruin or monument or object of antiquity situated on lands owned or controlled by the government of the United States), a cultural resources field survey should be conducted. The field survey shall be confined to the footprint of the area to be disturbed during the work effort. A plan describing the procedures and work areas should be prepared by an archeologist and submitted to the SHPO. The field survey should be planned to determine if potentially significant cultural resources are present on the property and may include subsurface testing, recording revealed stratigraphy, and processing and analyses of recovered artifacts.

4.7.4.12.6. The Cultural Resources Plan should include a Cultural Resources Monitoring Plan.

4.7.4.12.6.1. After the initial coordination with the appropriate agencies and the cultural resources field survey (if necessary), a cultural resources monitoring plan shall be prepared to address historical, archaeological, and other cultural resources. This plan shall define procedures for identifying and protecting historical, archaeological, and other cultural resources known to be on the project site and/or identify procedures to be followed if historical, archaeological, or cultural resources not previously known to be on site or in the area are discovered during project execution. The plan must include methods to assure the protection of known or discovered resources and identify lines of communication among contractor personnel, USACE personnel, and appropriate agency personnel.

4.7.4.12.6.2. The plan shall include discussion on the project location, background history and environment, site type found in similar environmental ecosystems, and the proposal for performing the monitoring with minimal impact to the ongoing work.

4.7.4.12.6.3. The plan shall address steps to be taken during excavation or other project execution activities, if any previously unidentified or unanticipated historical, archaeological, or cultural resources are discovered or found. It should be clear that all activities that may damage or alter such resources would be temporarily suspended. Resources covered by this paragraph include, but are not limited to, any human skeletal remains or burials; artifacts; shell, midden, bone, charcoal, or other deposits; rock or coral alignments, paving, wall, or other constructed features; and any indication of agricultural or other human activities.

4.7.4.12.6.4. The plan shall clearly provide a reporting process upon such discovery or find to immediately notify the KO and the PM so that the appropriate authorities can be notified and a determination made as to the significance of the find and what, if any, special disposition of the finds should be made. All activities that might result in impact to or the destruction of these resources should cease and the area should be secured to prevent employees or other persons from trespassing on, removing, or otherwise disturbing such resources. The plan should clearly address provisions to continue work in un-impacted areas.

4.7.4.12.7. A qualified archeologist is required to manage all cultural resource planning efforts and to participate in any field mitigation efforts. At a minimum, a qualified archeologist is a person with a graduate degree in archeology, anthropology, or closely related field and who has at least one year of full-time professional experience or equivalent specialized training in archeological research, administration, or management and at least four months of supervised field and analytic experience in general North American archeology. Depending on site-specific resources, additional qualifications may be required.

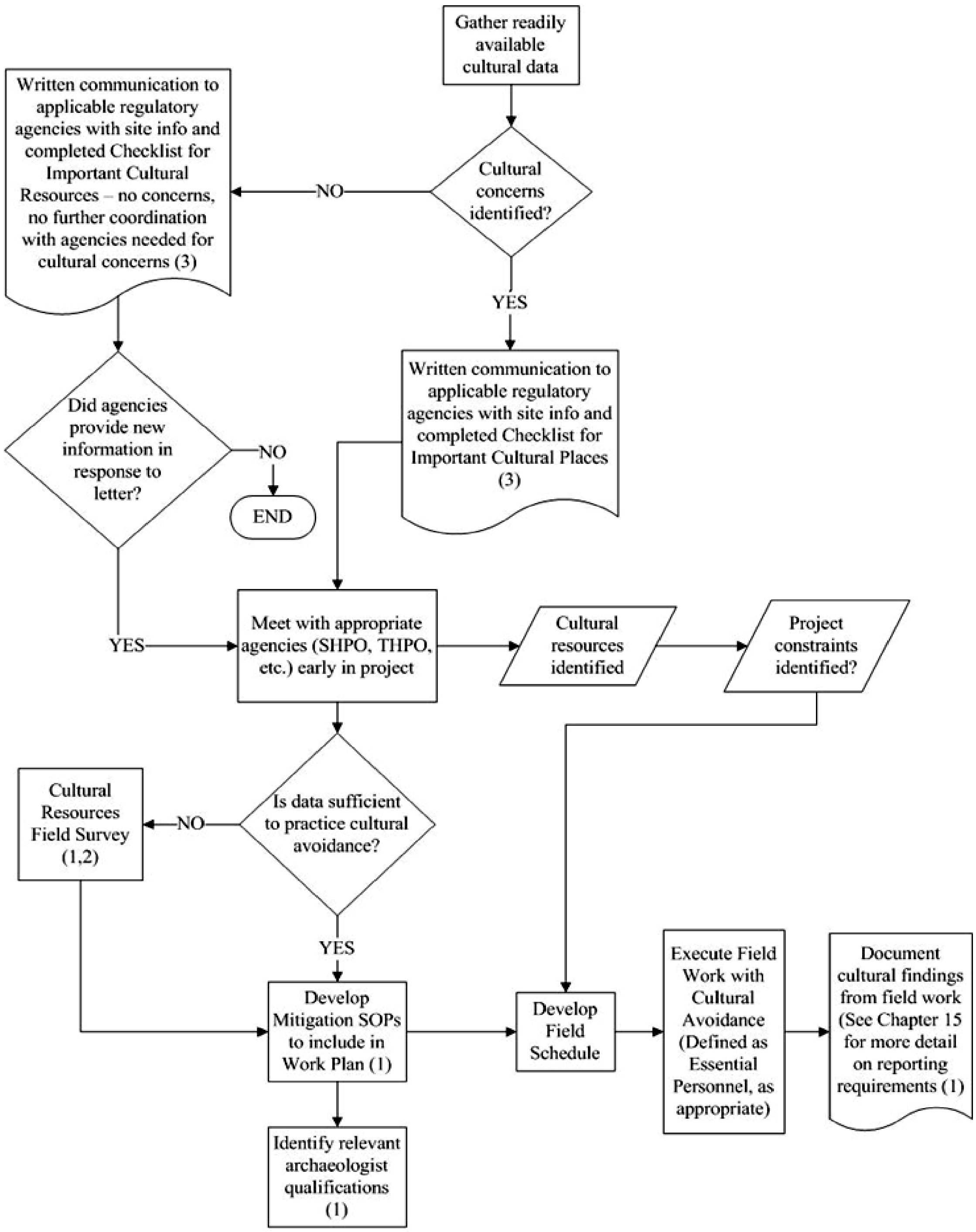


**Figure 4-3 Cultural Resources Planning Process**

(1) Requires coordination with appropriate agencies
(2) Evaluation can be conducted by the agency, USACE, or under contract.
(3) Required to be submitted into project file and database of record (e.g., FRMD)

1) Historic property (any prehistoric or historic district, site, building, structure, or object as defined by 36 CFR 800 - Protection of Historic Properties included in, or eligible for inclusion in, the National Register of Historic Places (NRHP), whether or not such eligibility has been determined formally), including artifacts, records, and material remains related to such a property or resource
2) Cultural items as defined in the NAGPRA (25 USC 3001)
3) American Indian, Native Alaskan, or Native Hawaiian sacred sites as required in American Indian Religious Freedom Act and defined in EO 13007, “Indian Sacred Sites”
4) Archaeological resources as defined in section 470 aa-mm of the Archeological Resources Protection Act of 1979 (16 U.S.C. 470cc(i))
5) Archaeological artifact collections and associated records as defined in 36 CFR 79 – Curation of Federally Owned and Administered Archaeological Collections
6) National monuments as defined in the Antiquities Act of 1906 (16 USC 431-433)
7) Significant scientific, prehistorical, or archaeological data, as defined by the Archaeological and Historic Preservation Act
8) Shipwrecks or aircraft on the bottoms of lakes, rivers, bays, and the ocean under U.S. territorial waters, as defined by the Abandoned Shipwrecks Act and regulated under the Sunken Military Craft Act
9) National Historic Landmarks, as defined in Historic Sites Act of 1935 (16 U.S.C. 461; 36 CFR 65)
10) Historic trails, trail sites, and trail segments, as defined in the National Trails System Act of 1968 (16 U.S.C. 1241)
11) Historic battlefields, as defined in the American Battlefield Protection Program Act of 1996, as amended by the Civil War Battlefield Preservation Act of 2002 (16 U.S.C. 469k-l)

Note: This checklist should be used as a basis for the determination but may not be all-inclusive. For example, it does not address any state-specific designations that may be applicable or traditional cultural properties that may be eligible for inclusion on the NRHP. A qualified archeologist should perform completion of the determination.

Figure 4-4: Checklist for Important Cultural Resources

4.7.4.12.8. During cultural resource avoidance, all results and findings shall be documented. Documentation should include specific information about cultural resources associated with the MRS, such as resources identified and avoidance efforts (e.g., transects relocated). Documentation also shall include the site archaeologist’s field notes. All documentation shall be incorporated into the phase-specific report for the project, which is discussed further in Chapter 13.

4.7.4.12.9. The results of the cultural resources survey and cultural resources avoidance activities during project execution shall be reported IAW the procedures described in Section 13.2.

4.7.4.13. Include an Erosion and Sediment Control Plan. This plan identifies the type and location of the erosion and sediment controls to be provided. The plan must include monitoring and reporting requirements to assure that the control measures are in compliance with the erosion and sediment control plan and federal, state, and local laws and regulations. The focus of the plan should be to maintain erosion and sediment controls such that water quality standards are not violated as a result of project activities. The area of bare soil exposed at any one time by construction operations should be kept to a minimum. Temporary and permanent erosion and sediment control best management practices should be identified and may include, but not be limited to, vegetation cover, stream bank stabilization, slope stabilization, silt fences, construction of terraces, interceptor channels, sediment traps, inlet and outfall protection, diversion channels, and sedimentation basins. Procedures for the following, unless covered elsewhere, should be included in the erosion and sediment control plan:

a. Controlling dust and emissions;

b. Minimizing sound intrusions (provide relevant reference to the AAP);

c. Minimizing areas of disturbance;

d. Protecting and restoring trees and shrubs; and

e. Post-activity cleanup.

4.7.4.14. The contractor's personnel must be trained in relevant aspects of environmental protection and pollution control. The contractor must conduct environmental protection / pollution control meetings for all personnel prior to commencing project activities. Additional meetings must be conducted for new personnel and when site conditions change. Include in the training and meeting agenda relevant aspects of the EPP that are not already addressed in the daily safety and occupational health briefings (e.g., installation and care of devices, vegetative covers, and instruments required for monitoring purposes to ensure adequate and continuous environmental protection / pollution control; protection of archaeological sites, artifacts, wetlands, and endangered species and their habitat that are known to be in the area). This general site briefing is required in addition to any specialized training relevant to implementation of the Ecological Resources Plan and the Cultural Resources Plan.

4.8. Interim Holding Facility Siting Plan / Physical Security Plan. An IHF Plan and a PSP must be prepared for projects that involve CWM response actions. The two plans should be included as appendices to the UFP-QAPP. The IHF is constructed on site for the receipt and temporary storage of CWM, pending on site disposal or removal from the site. The IHF Plan provides information about the temporary storage of CWM in a safe, secure, and environmentally sound manner. EP 75-1-3 provides instructions for addressing the layout, explosive safety requirements, and security measures for the IHF at CWM projects as part of the IHF Plan. EP 75-1-3 also provides instructions for preparing the PSP, which describes the security criteria to be employed during CWM operations.

4.9. Waste Management Plan.

4.9.1. MR project field activities can involve the generation, management, and disposal of various waste streams, which may include investigation-derived waste (IDW), such as soil cuttings, PPE, sampling equipment, purge water, decontamination water, solvents, MD, material contaminated with chemical agent, and the solutions used for decontaminating equipment contaminated with chemical agent. See EP 75-1-3 for specific guidance on managing chemical-agent-containing IDW. For sites where radiological contamination may exist (e.g., sites where depleted uranium has been used), refer to ALARACT 188/2011 for additional information for screening scrap for radioactive materials.

4.9.2. The purpose of the WMP is to present the waste management practices and procedures that will be followed for the types and quantities of waste expected to be generated during the field activities during MR projects. The WMP should identify the waste management activities conducted during the storage, preparation, and/or disposal of waste, including waste characterization, packaging, storage, and management while in storage. The WMP also should identify the organizations, and preferably the individuals, who will be responsible for signing hazardous material shipping papers and hazardous waste manifests. It is the responsibility of the PM to verify that all project personnel are aware of the requirements stipulated in the WMP.

4.9.3. The WMP provides information on how wastes, including potentially hazardous wastes associated with MR project activities, will be managed and disposed of. In addition, a secondary goal of the WMP is to ensure that waste minimization practices are followed, to the extent practical, to reduce the volume of waste that will be generated, stored, and removed from the site for disposal.

4.9.4. The WMP should address all applicable requirements, including USEPA's hazardous waste regulations at 40 CFR Parts 260-268 and the National Contingency Plan at 40 CFR Part 300. See USEPA/540/G-91/009 (Management of Investigation-Derived Waste During Site Inspections) for additional information.

4.9.5. The WMP shall provide the name(s) and qualifications of the person(s) responsible for manifesting hazardous waste to be removed from the site, if applicable.

4.9.6. The WMP shall identify any subcontractors responsible for the transportation or disposal of hazardous or solid waste. The licenses and permits of all solid waste disposal sites must be provided as part of the WMP. If the hazardous waste disposal facility must be identified after the waste is characterized, an addendum to the WMP shall be prepared and submitted with the relevant information.

4.9.7. For CERCLA responses involving off-site disposal of solid waste, the WMP shall identify disposal facilities meeting acceptability criteria IAW 40 CFR Part 300.440 (CERCLA Off-site Rule).

4.9.8. Evidence of the disposal facility's acceptance of any hazardous or solid waste must be attached to the phase-specific report. The report must document the total amount of each type of waste generated (nonhazardous vs. hazardous) and indicate the total amount of waste diverted (in cubic meters), the percent that was diverted, and the means of diversion.

4.9.9. A recycling and solid waste minimization section should be included for projects anticipated to yield hazardous waste that will be taken for off-site treatment, storage, and disposal. This section should include a list of measures to reduce consumption of energy and natural resources. The section also should detail the contractor's actions to comply with and participate in federal, state, regional, and local government-sponsored recycling programs to reduce the volume of solid waste at the source.

4.9.10. The WMP should address wastewater disposal.

4.9.10.1. Non-Hazardous Wastewater. If wastewater will be disposed of on site, the following additional requirements apply:

4.9.10.1.1. If land application is the method of disposal for the wastewater, the plan must include a sketch showing the location for land application along with a description of the pretreatment methods to be implemented.

4.9.10.1.2. If surface water discharge is the method of disposal, include a copy of any permit, if required, and associated documents as an attachment prior to discharging the wastewater. It should be remembered that under CERCLA, the USACE has permit waiver provisions for on-site actions as well as ARAR identification and protection.

4.9.10.1.3. If disposal is to a sanitary sewer, the plan must include documentation that the wastewater treatment plant operator has approved the flow rate, volume, and type of discharge.

4.9.10.2. Hazardous Wastewater. For wastewater meeting the definition of hazardous waste under RCRA, RCRA requirements for disposal apply and typically require disposal at a RCRA-permitted hazardous waste treatment, storage, and disposal facility.

4.10. Explosives Management Plan.

4.10.1. This plan describes how demolition explosives will be managed, planned, and implemented during MR operations using appropriately qualified personnel, equipment, and procedures. It also describes how recovered MEC will be managed. The Explosives Management Plan is required for all project sites where explosives will be used to perform demolition operations. If the project site is at an active military installation or other site and the installation's EOD unit will perform all demolition, then the PDT may choose to state this within the Explosives Management Plan and attach a memorandum of agreement with the local EOD unit. The performing EOD unit will need to follow the requirements of the Explosives Management Plan.

4.10.2. The contractor should prepare a detailed plan for the management of explosives IAW FAR 45.5; local and state laws and regulations; Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF) Publication 5400.7; DA PAM 385-64; and Department of Transportation (DOT) regulations.

4.10.3. At each project site, the responsible party shall have and, upon request, make available to any local, state, or federal authority a copy of any license/permit obtained authorizing the contractor to purchase, store, transport, and use explosives.

4.10.4. The Explosives Management Plan will include the following:

4.10.4.1. Acquisition.

a. A description and estimated quantity of explosives to be used

b. The acquisition source and a statement addressing whether explosives will be government furnished or purchased from a commercial vendor

c. If explosives are to be contractor acquired, identification of each explosive item in the equipment plan

4.10.4.2. Storage.

a. Establishment of explosives storage facilities

b. Physical security of explosives storage facilities

4.10.4.3. Transportation.

a. Procedures for transportation from storage facility to disposal locations at the project site

b. Requirements for vehicles transporting explosives at the project site

4.10.4.4. Receipt Procedures.

a. Receipt procedures accounting for each item of explosives from initial delivery to the site (e.g., from an installation ammunition supply activity, commercial vendor, or a previous contractor at a site) until the item is expended or the KO relieves the contactor from accountability

b. Identification of individuals authorized to receive, issue, transport, and use explosives by contract position title and procedures for assumption of accountability by those individuals

c. Procedures for reconciling receipt documents, proposed receipt intervals, and discrepancies in quantities shipped and quantities received

4.10.4.5. Inventory.

a. Procedures for physical inventory of explosives in storage facilities

b. Procedures for reconciling discrepancies resulting from inventories

4.10.4.6. Inspection of Magazines.

a. The PDT must follow the criteria reiterated here from the ATF 5400 manual for ATF Type II magazines located on USACE project sites. Any person storing explosive materials shall inspect their magazines every 7 days or more frequently if required by installation-specific requirements. This inspection need not be an inventory but must be sufficient to determine whether there has been unauthorized entry or attempted entry into the magazines or unauthorized removal of the contents of the magazines.

b. For those magazines that are used on installations, follow the local regulations and directives.

4.10.4.7. Procedures upon Discovery of Lost, Stolen, or Unauthorized Use of Explosives. Proper authorities shall be notified in writing within 24 hours of the event. Immediately notify the KO by telephone and follow up with a written report within 24 hours.

4.10.4.8. Procedures for Return to Storage of any Daily Issued Explosives not Expended.

4.10.4.9. Procedures for Disposing of any Remaining Explosives at the End of the Contractor's Site Activities.

4.10.4.10. Economic Analysis of Different Alternatives for Explosives Management (e.g., just-in-time delivery versus storing explosives in a magazine on site).

4.11. Munitions Response Safety Submissions and Site Plans.

4.11.1. Munitions Response Safety Submissions and Site Plans are required for environmental restoration activities that involve intentional physical contact with MEC, or chemical agent (CA), regardless of CA configuration; or the conduct of ground-disturbing or other intrusive activities in areas known or suspected to contain MEC or CA. The nature and intent of site activities determines what type of document is required. See EM 385-1-97 for details.

4.11.2. Safety submissions and site plans ensure that all applicable DoD and DA explosives safety standards are applied to a military munitions response action. These submissions must be approved prior to MEC operations or the placement of explosives on site. The safety submission must have a Direct Reporting Unit (DRU) approval, an Army approval, as well as a DDESB approval.

4.11.3. A Munitions Response Explosives Site Plan (MRESP) or, when appropriate, a Munitions Response Chemical Site Plan (MRCSP) is required for MRS investigations or characterizations (i.e., SI, EE/CA or RI/FS) that involve the intentional physical contact with MEC or CA, regardless of configuration. Such site plans will address areas (e.g., magazines) used for the storage of commercial or military demolition explosives, MEC or CA, regardless of configuration; planned or established demolition or disposal areas; and the MRA, MRS, or response area boundaries. MRS investigation and characterization are used to collect the information needed to design the required munitions response and to prepare, as appropriate, an Munitions Response Explosives Safety Submission (MRESS) or Munitions Response Chemical Safety Submission (MRCSS) for the selected response.

4.12. Community Relations Plan.

4.12.1. CRPs, formerly referred to as Public Involvement Plans, Community Involvement Plans, or Public Participation Plans, are required to establish and maintain programs and procedures for educating the public of the hazards associated with MEC and MC, as well as to inform the public of the fieldwork in the MR project that may have impacts to nearby residents and workers.

4.12.2. A good CRP facilitates two-way communication by encouraging active involvement by the stakeholders, which better ensures eventual project success and stakeholder acceptance. CRPs are required upon initiation of the RI phase. They can be prepared in earlier phases, if needed to assist with planning and execution of public involvement activities. Guidance for developing and implementing the CRP is available in the following documents:

a. EP 200-3-1

b. ER 200-3-1

c. The FUDS Public Involvement Toolkit (available at http://www.hnd.usace.army.mil/oew/CX_PTR.aspx)

4.13. Risk/Hazard Assessment Planning.

4.13.1. The CERCLA process requires that a BRA be performed as part of the RI phase of a project; however, the level of effort should be commensurate with site complexity. Risks from MC contamination in environmental media (e.g., soil, groundwater, sediment, surface water) should be based on environmental sampling data collected IAW the UFP-QAPP. Guidance for how to conduct risk assessments is contained in Section 12.4.

4.13.2. The assessment of the hazards associated with MEC also is intended to be used as part of the CERCLA process to help project teams evaluate current or baseline explosive safety hazards to people, as well as the relative reduction hazards associated with CERCLA removal or remedial action alternatives. Guidance for how to conduct a MEC HA is contained in Section 12.3. The data collection requirements to conduct a MEC HA should be described in the appropriate worksheets of the UFP-QAPP. A MEC HA is performed using a computer-based MEC HA spreadsheet.

4.13.3. The BRA is completed as part of the RI phase of a project for sites where the PA/SI indicates a potential risk to site receptors may be present. The level of planning for the risk assessment can vary significantly in level of complexity, depending upon various factors, such as the likelihood of chemical release to the environment, site complexity, regulatory context, and potential for public/stakeholder involvement. The CSM and the TPP process provide information necessary for the risk assessor to determine the level of effort required to achieve the project risk management objectives. EM 200-1-12 and Sections 2.2 and 12.2 of this EM provide guidance on CSM development. The initial conclusions of the CSM and the planning for the BRA should be documented in Worksheet 10 (Problem Definition) of the UFP-QAPP. Worksheet 10 provides sections for text to state the problem, define environmental questions to be answered, and present rationale for project decisions. The anticipated complexity of the BRA required to address the problem and the environmental questions should be stated clearly in Worksheet 10. Data collected during project implementation may change the anticipated complexity of the BRA. The decision process used to elevate the complexity of the BRA also should be documented in Worksheet 10.

4.13.4. HHRA. The level of complexity for the HHRA is based on the CSM, which will be documented in Worksheet 10 of the UFP-QAPP.

4.13.4.1. Simple MRSs (e.g., ranges with minimal use) have the types and sources for risk-based screening criteria documented in the UFP-QAPP. Comparison to background concentrations and screening values, typically for selection of chemicals of potential concern (COPCs) / chemicals of potential ecological concern in the BRA, may be all that is necessary to address the potential for risks at such sites. If not, the risk assessment calculations are simple and straightforward. Worksheet 10 is used to document the level of complexity for the HHRA based on the initial CSM and TPP process. The DQOs required to make risk-based decisions for the site should be documented in Worksheet 11 (Project Quality Objectives / Systematic Planning Process Statements) and Worksheet 12 (Measurement Performance Criteria Table). The appropriate risk-based screening criteria and documentation of the source(s) of the screening criteria should be presented in footnotes to Worksheet 15 (Reference Limits and Evaluation Table). See Table 12-1 in this EM for some sources of risk-based criteria. Worksheet 15 of the UFP-QAPP must be used to provide the screening level and background concentrations based on natural and anthropogenic sources. Finally, Worksheet 15 of the UFP-QAPP is used to document quantitation limits and detection limits with respect to screening levels.

4.13.4.2. More complex sites with MEC, multiple exposure media (soil, water, and groundwater), and fate and transport issues may require a detailed approach to define how the HHRA is structured and what investigation details are needed to determine the data collection needs to specifically support the risk assessment. The HHRA is conducted in four major tasks: 1) Problem Formulation, 2) Exposure Assessment, 3) Toxicity Assessment, and 4) Risk Characterization, as described in Section 12.4.1. The PDT also needs to document sources of exposure assumptions and toxicity values used to develop the quantitative risk assessment. UFP-QAPP Worksheet 14 (Summary of Project Tasks) is used to document the proposed approaches for HHRA tasks. MC generally are well represented in existing toxicity databases, including Integrated Risk Information System, Provisional Peer-Reviewed Toxicity Values (PPRTV), and Regional Screening Levels. The United States Army Institute of Public Health (USAIPH) can be consulted for toxicity information, if required. Documentation of the application and justification for any site-specific exposure assumptions or factors will be presented in the toxicity assessment task in Worksheet 14.

4.13.5. ERA. Similar to the HHRA, the level of complexity for the ERA is based on the CSM, which is documented in Worksheet 10 of the UFP-QAPP.

4.13.5.1. Each potentially impacted exposure media (soil, air, and/or water) and potentially exposed receptor population is documented in Worksheet 10 as part of the initial CSM. Where deemed appropriate by the PDT, the UFP-QAPP (Worksheet 11) must identify field activities required to characterize the environmental setting and determine appropriate assessment and measurement endpoints, such as threatened and endangered or biological surveys, habitat evaluations, wetland delineation, or water body classifications. See Section 12.4.2 for more information.

4.13.5.2. For simple MRSs, a Screening-Level Ecological Risk Assessment (SLERA) may determine that ecological risks are minimal, and no further evaluation is necessary. Worksheet 14 of the UFP-QAPP is used to document what information is necessary to characterize habitat, determine receptor species, establish site-specific exposure factors, and summarize the information and sources concerning the screening-level food chain analysis as part of the task description for the exposure assessment, if applicable.

4.13.5.3. The UFP-QAPP for a project that includes a Baseline Ecological Risk Assessment (BERA) must define the types of site-specific field and laboratory investigations required to assess potential risk to ecological receptors. The site-specific field and laboratory investigations should be documented in Worksheet 11 of the UFP-QAPP. BERAs can vary significantly depending upon the size and complexity of the documented release. The UFP-QAPP includes descriptions of the food web model, assumptions, and methodologies to quantify hazards as part of the task descriptions for the exposure assessment, toxicity assessment, and risk characterization in Worksheet 14. Information in the UFP-QAPP for a simple BERA may be limited to descriptions of field biota and habitat surveys, standard chemical data collection methods, DQOs, and statistical evaluations to calculate chemical- and media-specific exposure point concentrations (EPCs) as part of the problem formulation task in Worksheet 14. Sources of toxicity reference values also are defined for the BERA as part of the task description for the toxicity assessment task. As with the HHRA, MEC may have constituents that are not well represented in standard ecological toxicity databases. In these cases, the USAIPH can be contacted for toxicity information (http://usaphcapps.amedd.army.militox/herp.aspx). For more complex sites, the UFP-QAPP also should provide for collection of plant and animal tissue samples for site-specific food web evaluations, toxicity testing in soil and sediment invertebrates and other aquatic species, and site-specific chemical uptake studies. In all cases, Worksheet 11 of the UFP-QAPP should be used to provide the justification for the recommended investigations, regulatory requirements, sample collection and handling requirements, and laboratory testing and analytical requirements, including DQOs.

# CHAPTER 5

## Geospatial Data and Systems

5.1. Introduction.

5.1.1. The purpose of this chapter is to describe and discuss the geospatial data and system (GDS) considerations, including location surveying and mapping. The PDT should develop a project-specific GDS, location surveying, and mapping requirements for inclusion in the SOW for each MR project. Application of procedures required for surveying and mapping may vary depending on the type of contracting methodology being used to execute the work; however, they should be used to the extent practicable.

5.1.2. USACE has various contract vehicles that may be used for obtaining location surveying and mapping services. Services may be supplied by the government as government-furnished information / government-furnished equipment or may be requested within the SOW of the MR. Some MR projects may not require any specialized capabilities, while others may require comprehensive capabilities.

5.2. Requirements for the Acquisition and Access of Geospatial Data.

5.2.1. This chapter presents guidance in developing GDS requirements associated with an MR, specific SOW requirements, and technical or management considerations. ER 1110-1-8156, Engineering and Design - Policies, Guidance, and Requirements for Geospatial Data Systems establishes general criteria and presents guidance for the acquisition, processing, storage, distribution, and utilization of geospatial data.

5.2.2. EM 1110-1-2909, Geospatial Data and Systems identifies standards for GDS acquired, produced, and/or utilized in support of an MR. Many techniques may be used to acquire the geospatial data required in support of an MR. Requirements for obtaining these data should be results oriented and not overly prescriptive or process oriented IAW EM 1110-1-2909. Project requirements should set forth the end results to be achieved and not the means, or technical procedures, used to achieve those results. They should succinctly define GDS requirements as derived from the functional project requirements developed by the PDT and reference EM 1110-1-2909 and other applicable industry standards.

5.3. Data Quality Objectives.

5.3.1. Archive Review. The PDT will review the archival records of the project area or installation in which the project is located and inventory all existing GDS information prior to developing site-specific DQOs. EM 1110-1-2909 shall be used as guidance when no other standards or legacy system exists.

5.3.2. GDS. The PDT will review the extent of GDS currently utilized by the MMDC, district, customer, and stakeholders. Any automated system that employs or references data using absolute, relative, or assumed coordinates is considered a GDS. These include GIS, land information systems, remote sensing or image processing systems, computer aided design and drafting (CADD) systems, and automated mapping / facilities management systems. The selected GDS should accomplish today's mission but also allow for future reuse or use of the geospatial data by others without translation. Production of geospatial data in multiple formats for distribution or use should be avoided whenever possible. This means that the data formats selected should be open rather than proprietary. For example, Tagged Image File Format (TIFF or ".tif") files should be used to store imagery rather than Photographic Experts Group (JPEG) (or ".jpg") files or bitmap (BMP, or ".bmp") files, as TIFF is considered an open standard. Compatible formats for spatial data also should be selected whenever possible (e.g., ArcGIS shapefiles, which usually can be shared among several software applications). Note that many of these file types contain auxiliary files that must also be provided when transferring files. For example, ArcView shapefiles (i.e., .shp files) require that the auxiliary files (.dbf, .prj, .sbn, .sbx, .shx, .xml files) be located within the same folder in order for the files to be displayed properly in ArcView. Project requirements may dictate the use of a particular proprietary software package and/or database format. In these cases, the final data product should be exported to an open format at the close of the project to ensure long-term data survivability and compatibility. For example, tabular databases should be exported to an American Standard Code for Information Interchange (ASCII) format, with appropriate documentation. Spatial data should be exported at the close of the project to an open format, such as Spatial Data Transfer Standard or Drawing Interchange File format.

5.3.3. Spatial Coordinate Reference System. All MR projects should be adequately connected to nationwide or worldwide geographic reference systems. All geospatial data should be indexed to existing local, state, or national control monuments and referenced to an appropriately recognized installation, local, state, or worldwide coordinate system, as specified by the PDT. The PDT should evaluate existing monuments to determine whether they are suitable for use during an MR action. This evaluation should include verification of the last recovery data, the shape of the monument during the last recovery and the type of the monument. The PDT should select a spatial coordinate reference system that is compatible with existing district or customer GDS activities. Unless otherwise indicated, it is recommend that all spatial data be stored using the Universal Transverse Mercator (UTM) Coordinate System, using either North American Datum of 1983 or World Geodetic System of 1984 for horizontal control with the most current Geoid model (Geoid 09). Horizontal coordinates should be stored using metric units. Vertical control, if required, also should be based on metric units and referenced to North American Vertical Datum of 1988. Project-specific requirements may dictate the use of an alternate coordinate system, datum, and measurement units, but deviations from this standard should be made only after careful deliberation and with full recognition of the potential impacts. For projects located outside the continental United States, local conditions may warrant the use of an alternate vertical datum. Potential project impacts from using an alternate coordinate system include, but are not limited to, the following:

a. Positional errors could get perpetuated into later projects.

b. Local coordinate systems and relocated benchmarks, if not in UTM, need to fully define all input to the coordinate system (e.g., prime meridian, units, system).

c. Extra care needs to be taken to ensure that the correct units are used throughout the project (i.e., some software use the term feet to denote U.S. Survey Feet, while others use the term feet to denote International Feet).

5.3.4. Geospatial Data Standards. GDS users need geospatial data standards to manage data, reduce redundant data, make systems more efficient, and lower project costs. At this time, the DoD's Spatial Data Standards for Facilities, Infrastructure, and the Environment (SDSFIE) should be specified for all deliverables of collected geospatial data, with the exception of DGM data, which have their own data requirements that are discussed further in Chapters 6 and 11. The SDSFIE data standard is the most recent requirement at the time of writing but may be superseded by new data standards and/or the requirements of the project's PWS or SOW. The SDSFIE data standard is available online at http://www.sdsfie.org. The PDT should develop additional site-specific standards for the format, transfer, and storage of all geospatial data, including metadata, consistent with EM 1110-1-2909. Factors influencing formulation of project-specific standards include:

a. compatibility with selected GDS without modification or additional software;

b. format of existing digital data and geospatial-referenced mapping; and

c. usability by all parties of concern, including stakeholders.

5.3.5. Measurement Units. Geospatial data produced in support of an MR project should be recorded and plotted in the units prescribed for the project by the district or customer. The use of metric units is recommended unless superseded by project-specific requirements.

5.3.6. Control Markers. Project control markers may consist of markers and/or benchmarks established by any federal, state, local, or private agency with positional data within the minimum acceptable accuracy standards prescribed by the PDT. The PDT may require an increase in existing project control markers. Ties to local USACE or installation project control and/or boundary markers are absolutely essential and critical except when unfeasible or cost prohibitive. In order to minimize scale and orientation errors, at least two existing markers should be used as a baseline for the project geospatial coordinate reference system. Further guidance on survey markers and monumentation can be found in EM 1110-1-1002.

5.3.7. Accuracy. Every observed or measured spatial data element contains errors of a certain magnitude due to a variety of causes. The PDT should evaluate data requirements and develop acceptable limits of error (accuracy and precision) based upon the nature and purpose of each location surveying and mapping activity or product. Accuracy requirements may vary between projects, as well as between separate tasks on an individual project. The PDT should evaluate the positional accuracy requirements for each data type and project task and outline QC procedures in the QC plan or UFP-QAPP to ensure the project's positional accuracy requirements and DQOs are met. Engineering and construction surveys normally are specified and classified based on the minimum acceptable horizontal (linear) point closure ratio and vertical elevation difference standard. Standardization, or calibration, of equipment and instruments used in acquiring geospatial data and producing location survey and mapping products is required to improve the accuracy of the integrated conclusions. See Section 6.4 for guidance on the use of geophysical survey positioning and navigation systems and their related accuracy and precision.

5.3.8. Reliability. The development of an effective GDS facilitates a systemized approach to an MR project using all digital data and life cycle management of all applicable geospatial data. GDS should be stored IAW Army security levels; the PDT also should consider project-specific security concerns. If security allows, provision should be made on larger-scale projects to facilitate the sharing and dissemination of data using Web-based tools and applications where possible (e.g., Web-based mapping services). This would avoid data duplication and serve to centralize and standardize database stewardship functions IAW the overall goal of improved life cycle data management. The project GDS should provide a full digital record of all on-site activities with a reproducible trail to support ongoing and future Administrative Record decisions. The GDS designated in the SOW by the PDT should provide reliable results, support greater overall productivity, and lower total project costs.

5.3.9. Data Preservation. The closeout of a project should include steps to archive the data using open data formats as described above and using stable digital media to ensure long-term survivability. Data storage methods that preserve data after project closeout should be documented in the project's UFP-QAPP. The specific media chosen will change as the technology changes; however, care should be taken to select only the most stable and widely used formats. These media will be refreshed on a regular 5- to 10-year cycle, and it is of utmost importance that the media be readable and accessible when the scheduled refresh occurs.

5.4. Scope of Work.

5.4.1. General. PDT personnel with detailed knowledge of the project history, archival information, various GDS platforms, location survey and mapping methodologies, and project-specific data requirements should prepare the GDS standards and requirements for each MR project SOW. The SOW requires consideration of the following in development of the UFP-QAPP:

a. Project and property boundaries

b. MEC types, hazard levels, and contamination levels

c. Potential sources of MC, including firing lines, targets, open burning / open detonation (OB/OD) areas, etc.

d. Project location, size, topography, and vegetative cover

e. Extent of existing planimetric features

f. Density and accuracy of existing control markers

g. Mission and objectives of the MR

h. Positioning requirements of proposed geophysical detection systems

i. Data formatting, transfer, and storage

5.4.2. Personnel Requirements. The PDT should ensure that the MR project SOW specifies that a qualified GIS manager should manage all GDS activities. The PDT will ensure that the SOW also discusses personnel requirements for a Registered Land Surveyor (RLS) or Professional Land Surveyor (PLS) and a qualified UXO technician for geodetic surveys.

5.4.2.1. GIS Manager. The SOW should specify that the individual have a minimum of 3 years of direct experience managing geospatial data systems within the specified system environment (i.e., ArcGIS, GeoMedia, or Modular GIS Environment). The GIS Manager also should have an understanding of Army and DoD GDS requirements, as specified in ER 1110-1-8156.

5.4.2.2. RLS or PLS. The PDT should ensure that the MR SOW specifies that boundary work, legal descriptions, and parcel closure information be completed under the responsible charge of an RLS/PLS. The RLS/PLS should be registered and/or licensed by the appropriate Board of Registration, or an acceptable equivalent, for the state in which this work will be conducted. The RLS/PLS is only required to sign drawings that contain boundaries, control monument locations, legal descriptions, or parcel closure information. An RLS/PLS is not required to oversee site characterization grid coordinates and ordnance location data. In addition, the Field Surveyor assigned to the MR project will have a minimum of 5 years' experience as a Survey Party Chief.

5.4.2.3. UXO Technician II. The PDT also should assure that the SOW requires a qualified UXO Technician II to accompany the Field Surveyor during all field surveying and mapping activities. The UXO Technician II should conduct visual surveys for surface MEC prior to the Field Surveyor entering a suspected MEC-impacted area. A survey with a geophysical instrument should be performed at each intrusive activity location to ensure that the location is anomaly-free prior to the installation of monuments, driving stakes, or performing any other intrusive activity.

5.4.3. Safety. It is the responsibility of the PDT to assure that the contractor is informed in the SOW to follow all applicable safety requirements, for example EM 385-1-1, EM 385-1-97, ER 385-1-92, etc.

5.4.4. Resources. For general guidance on the development of surveying and mapping requirements, the PDT may reference EM 1110-1-2909. GPS surveying services may be required as an integral part of the location surveying and mapping effort. EM 1110-1-1003 provides technical requirements and procedural guidance for surveying with GPS and includes a guide specification for development of SOWs with GPS survey requirements.

5.5. Planning Considerations. Each MR project requires selection of an appropriate GDS that will accomplish the end objective(s) without wasting manpower, time, and money. The PDT should ensure that the following items are considered when planning for the location surveying and mapping task.

5.5.1. Spatial Data Reference System. See Section 5.3.3.

5.5.2. Project Control Markers.

5.5.2.1. The requirements for new or additional project control markers should be based on the availability of existing control markers, the type of location surveying equipment proposed, and the level of accuracy required for the type of activities proposed under the specific MR project. Permanent concrete monuments typically are used for project control; however, temporary control markers also may be used for shorter duration or smaller projects. New project control markers should be established outside areas that could be disturbed by MMRP or other activities. A PLS in the state where the work will be performed shall certify all established project control markers. Requirements for permanent and temporary markers are set forth in EM 1110-1-1002 and should be reviewed in consideration of the following:

a. Located within the project limits with a minimum separation of 100 meters (m)

b. Set 10 m from the edge of any existing road inside the project limits

c. Constructed with the top set flush with the ground and the bottom at a minimum of 0.6 m below frost depth

d. Temporary markers should be defined in the same manner as permanent markers, though they may consist of a larger wooden hub with adjacent guard stakes, a copper nail and washer, P-K nail, or other temporary spike set in relatively stable in-situ material

5.5.2.2. The minimum accuracy standards for horizontal and vertical control are Class I, Third Order or better. See Section 5.3.3 as well as the PWS/SOW for guidance on the appropriate Spatial Coordinate Reference System. If aerial photographs or orthophotography is used to provide the survey, the aerial targets used for control points should meet the same horizontal and vertical accuracy requirements detailed.

5.5.2.2.1. Monument Caps.

5.5.2.2.1.1. The caps for any new monuments established will be a 3-1/4- to 3-1/2-inch domed brass, bronze, or aluminum alloy and stamped in a consecutively numbered sequence. The proposed identification stamping for each monument will be provided in the Location Surveys and Mapping Plan consistent with the following:

(Project Name) - (Numerical Sequence) - (Year) (Contracting MMDC)

5.5.2.2.1.2. The dies for stamping the numbers and letters into these caps will be 1/8 inches to 3/16 inches in size. All coordinates and elevations will be shown to the closest one-thousandth of a meter (0.001 m) and one-hundredth of a foot (0.01 feet).

5.5.2.2.2. Monument Descriptions.

5.5.2.2.2.1. Monument descriptions are required for all control monuments established or used for the MR. These descriptions should be captured within the GIS database, in a standard relational database, or in a spreadsheet. Accompanying maps should show the location of the monument relative to other spatial features so that the monument could be recovered easily.

5.5.2.2.2.2. The monument descriptions and map(s) should include the following:

- Map showing location relative to reference marks, buildings, roads, railroads, towers, trees, etc. Map should include north arrow and scale.

- A text description in the database or spreadsheet telling how to locate the monument from a well-known and easily identifiable point.

- The monument's name or number (stored in the database or spreadsheet).

- The final adjusted coordinates and elevations in meters and feet (to the closest 0.001 m and 0.01 feet) stored in the database or spreadsheet.

5.5.3. Project Boundaries.

5.5.3.1. The PDT should consider whether staking out or marking project boundaries is required for a particular project. A key reason to mark out project boundaries is to ensure field personnel know the extent of the investigation and perform field activities up to those boundaries. This goal often can be accomplished with GPSs that can provide highly accurate positioning in real time. The use of GPSs in place of staking out project boundaries may represent a significant cost savings; however, the project boundary may require marking if GPSs cannot operate at the site (e.g., the site is in a densely wooded area where GPS navigation is not feasible).

5.5.3.2. If the PDT determines that marking out the project boundaries is required, the boundary should be marked out with permanent, semipermanent, or temporary markers. Permanent or semipermanent markers should consist of iron pipe or pins or other markers consistent with state or local subdivision requirements. Temporary markers may be used for shorter duration projects and may consist of wooden hubs or polyvinyl chloride pin flags. The accuracy standards for the location of project boundaries should be equal or greater than the minimum standards for property boundary surveys established by the state within which the project is located.

5.5.4. Local Control Points.

5.5.4.1. Local control points (i.e., grid corners and aerial targets) should be established using plastic or wooden hubs unless otherwise specified by the PDT.

5.5.4.2. The accuracy standards for aerial targets established as control points for aerial photographs or orthophotography should be the same as those prescribed for project control monuments. Accuracy standards for grid corners should be consistent with the mission and objectives of the MR effort.

5.5.5. Environmental Samples. All environmental samples should be located to an estimated or measured accuracy of approximately plus or minus 0.3 m (1 foot).

5.5.6. Digital Data Format and Storage and Coordinate Reporting.

5.5.6.1. There are two types of digital data typically generated during MR projects: geophysical mapping data and GIS data. Though geophysical data can be considered geographic information, it often is not practical to treat all geophysical mapping data as GIS data. Specifically, the databases used to store and interpret geophysical measurements are designed to work with specialized geophysical processing and interpretation software and often are not reformatted easily to meet GIS storage and reporting standards, and rarely does the need arise to do so. However, geophysical maps and anomaly databases produced as the result of geophysical data interpretations often are key components to the project GIS, and these often are produced according to the guidelines defined for the project GIS.

5.6. Munitions Response Site Delineation. When there is a requirement to realign or delineate an MRS (see Section 8.9 of this manual for further details), geographic information specialists may need to restructure or revise the existing GDS data in the appropriate database of record (e.g., FUDSMIS for FUDS properties). The geographic information specialist should verify that the acreages match at the beginning and end of a project, that boundaries do not get shifted, and that changes in the project's coordinate system do not introduce errors. The USACE FUDS Handbook on Realignment, Delineation, and MRS Prioritization Protocol Implementation (USACE, 2011) provides guidance on both realignment and delineation procedures. While the handbook's applicability is for FUDS projects, the guidance outlined within it may be extended to non-FUDS projects. For example, the rationale for MRS delineation may be based on anticipated response action for the MRS regardless of whether or not the MRS falls within the FUDS program.

# CHAPTER 6

## Geophysical Investigation Methodologies

6.1. Introduction.

6.1.1. The purpose of this chapter is to provide an in-depth understanding of how geophysics is used to detect metallic objects (e.g., UXO, DMM, scrap metal). The chapter first introduces the various systems used to collect and position geophysical data; then it explains, in general terms, the capabilities and limitations of geophysical and positioning systems. The various elements involved in planning and executing geophysical investigations then are described. Chapter 11 explains the different aspects of QC and QA of geophysical systems and presents various approaches for demonstrating and documenting QC of geophysical systems.

6.1.2. In this chapter, the term “geophysical system” defines the entire package of tools and procedures used for a given project or used to meet a specific project goal. Therefore, geophysical system can be thought of as the collection of tools and procedures that are finally selected for use from the array of technologies and deployment options available.

6.2. Geophysical Systems.

6.2.1. Geophysical systems comprise geophysical tools, positioning and navigation tools, deployment platforms, and data management and interpretation techniques. Instrument operators also are considered components of the geophysical system when their tasks are essential to the system’s performance.

6.2.2. Geophysical systems are broken down into the six fully integrated components, as follows. If any of these components are lacking, the overall geophysical system may not be able to locate effectively geophysical anomalies that may be TOIs. It is important to carefully plan and integrate all aspects of each component into the geophysical investigation and not to start fieldwork prematurely. The key components of a geophysical system are listed below.

6.2.2.1. Experienced Personnel. Personnel should be experienced with the theoretical and practical aspects of detecting relatively small anomalies and selecting anomalies that are likely TOIs (e.g., anomalies due to UXO or DMM) from multiple non-TOI anomalies that also are likely to be present (i.e., anomalies due to sources that have no explosive hazard). The selection and utilization of geophysical equipment is complex and requires qualified, experienced individuals. A qualified geophysicist should manage all MMRP geophysical investigations. A qualified geophysicist is a person with a degree in geophysics, engineering geophysics, or closely related field and who has a minimum of 5 years of directly related UXO geophysical experience. While various members of the PDT are critical in the determination of the goals and objectives of any geophysical investigation, the qualified geophysicist is required to ensure that those goals and objectives are met.

6.2.2.2. Site Preparation. Site preparation for geophysical investigations at MRAs includes making the ground surface safe for personnel to perform their tasks by removing vegetation and obstacles to meet equipment use needs.

6.2.2.3. Geophysical Systems Instrumentation. Geophysical instrumentation and related detection capabilities and limitations are discussed throughout this chapter.

6.2.2.4. Deployment Platforms. Geophysical platforms are discussed in Section 6.5.

6.2.2.5. Data Analysis. Geophysical data analysis includes accurately documenting the geophysical data collected, the steps used in analyzing the geophysical data, and different options available for interpreting the data. The geophysical data analysis work flow is discussed in Section 6.6.

6.2.2.6. Anomaly Resolution Procedures. These procedures define how the PDT verifies that each anomaly selected for intrusive excavation is resolved completely. The term anomaly resolution is used to describe all tasks and actions taken to verify or confirm that the dig results fully explain the source of the anomaly. Anomaly resolution is discussed in Section 6.6.9.

## 6.3. Geophysical Tools.

6.3.1. Introduction. Detection and location of geophysical anomalies that could be due to TOIs primarily depend on the ability of geophysical instruments to distinguish the physical characteristics of anomalies from those of the surrounding environment. The best currently available detection systems detect the metallic content of the TOIs not the explosive filler. There are several instruments that are not common that detect the explosive materials; however, they are designed to identify the content of recovered items and not to detect TOIs. This chapter focuses on the various geophysical detection systems currently available and widely used to detect geophysical anomalies associated with TOI, but it includes brief descriptions of some of the lesser-used systems and explains why their use is limited to specific missions within the UXO detection arena. This chapter does not address explosives "sniffers" or other technologies formulated around detecting the explosive components of munitions.

6.3.2. Detector Families. These various geophysical technologies are packaged in many ways. For simplicity, geophysical detectors are grouped into two main families of detectors based on how their data are interpreted. Analog geophysical tools are defined in this document as instruments that produce an audible output, a meter deflection, and/or numeric output, which are interpreted in real time by the instrument operator. DGM tools are defined in this document as instruments that digitally record geophysical measurements and geo-reference data to where each measurement occurred. This family of tools can be interpreted in real time, near real time, or any later time after data collection work is complete. DGM instruments include advanced electromagnetic induction (EMI) sensors that can collect DGM data either in a production or in a static mode. These advanced EMI sensors collect data from multiple directions and enable the classification of anomalies as a TOI or non-TOI (see Section 6.3.5 for further discussion of TOIs).

6.3.3. Analog Geophysical Tools. This family of detectors includes all handheld metal detectors and coin detectors and handheld ferrous locators. This family also includes those digital tools that can be operated as analog tools as defined above.

6.3.3.1. Analog Geophysical Surveys ("Mag & Flag" or "Mag & Dig"). Active EOD personnel and contractors use this approach to locate geophysical anomalies. Handheld metal detectors, such as magnetometers and electromagnetometers, are used to screen an area. Whenever the operator detects an anomaly, the operator places a small flag in the ground. Advantages of analog geophysical surveys include the following:

a. The geophysical operator can use real-time field observations.

b. They provide a precise anomaly location.

c. Anomalies can be excavated immediately following the survey.

d. They can be conducted with fewer vegetation and topographic constraints.

6.3.3.2. Analog Effectiveness. Analog geophysical surveys are effective in areas where vegetation and terrain limit the use of larger digital systems. For underwater surveys, analog approaches may be more effective than digital surveys in the surf zone if boats and digital systems cannot gain access. Limitations for both land and underwater analog surveys include the following:

a. In general, they do not detect as deep as DGM instruments (ESTCP, ITRC, SERDP, 2006).

b. Quality depends on operator training and demonstrated performance. Quality also is affected by human factors, such as attentiveness/distraction and hearing ability.

c. Developing rigorous QC measures that are capable of assessing the consistency of each operator's effectiveness and performance for the duration of the survey is more challenging and less precise than for digital geophysical methods.

d. A higher percentage of small, non-TOIs typically is detected during mag & flag surveys. This results in a higher number of intrusive investigations versus digital geophysical surveys.

e. Unable to evaluate electronic data further.

f. There is no permanent electronic record, as required by the joint USEPA/DoD Management Principles (see http://www.epa.gov/fedfac/documents/uxo_principles.htm).

g. Handheld magnetometers can detect ferrous metallic objects and are less sensitive to small amplitude anomalies and anomalies with low horizontal gradients than their digital counterparts.

h. EMI metal detectors can detect both ferrous and nonferrous metallic objects and have depth of detection capabilities that are related to the size of the coils and transmitter power. Handheld EMI metal detectors typically have smaller coils and less transmitter power than their digital counterparts and, therefore, typically have more shallow maximum depths of detection than their digital counterparts.

6.3.4. Digital Geophysical Tools. This family of detectors includes all geophysical tools capable of recording and geo-referencing geophysical measurements and includes all land-borne, airborne, and marine detectors.

6.3.4.1. Most magnetic and electromagnetic instruments have the capability to output a digital signal to a data logger that can be co-registered with positional information to develop a two-dimensional map of the characteristic that the instrument is measuring. Digital geophysical surveys are able to capitalize on the use of sensors with higher sensitivity, application of noise reduction techniques, and advanced data-analysis techniques. Advantages of digital geophysical surveys include the following:

a. Uniform process for data collection and analysis.

b. Geo-referenced location of data and anomalies.

c. No operator subjectivity (to place or not to place a flag).

d. Ability to further evaluate electronic data.

e. A permanent electronic record, as required by the joint USEPA/DoD Management Principles (see http://www.epa.gov/fedfac/documents/uxo_principles.htm).

f. Ability to define rigorous QC measures capable of detecting all/most possible failure modes for the geophysical survey.

g. Challenges for performing digital geophysical mapping include the following:

h. Decreased effectiveness in high clutter areas.

i. Vegetation and topographic constraints.

j. Quality dependent on operator training and demonstrated performance.

k. Defining anomaly selection criteria that meet the project team's needs in terms of identifying all TOIs while not selecting large numbers of non-TOI anomalies.

6.3.4.2. Additional challenges for digital geophysical systems in the underwater environment include the following:

a. Performing digital geophysical surveys in the shallow surf-zone may not be possible if there is significant wave action.

b. Positioning of the sensor in the marine environment is more complex than for land-based DGM operations and often is neither as accurate nor as precise as for land-based surveys.

c. The sensor often is "flown" above the sediment bottom, which increases the distance between the sensor and the potential TOI, thereby decreasing the depth below the sediment surface to which the sensor can reliably detect TOIs.

d. Defining rigorous QC procedures for underwater DGM surveys is more challenging than for land-borne DGM surveys.

e. The sensor must be navigated so that it avoids objects protruding from the sediment surface.

f. The speed of the current may prohibit the effective use of some technologies.

g. The depth of the water may preclude the use of some sensor configurations.

6.3.5. Advanced EMI Tools. This family of sensors includes all geophysical tools capable of exciting and recording the full EM response pattern from an object and geo-referencing geophysical measurements. Advanced EMI sensors offer the ability to evaluate anomaly selection criteria and to analyze the characteristics of detected anomalies to decide whether they should be placed on dig lists. Using anomaly characteristics as the basis, anomalies can be classified as either TOIs or non-TOI. TOIs typically are anomalies caused by UXO or DMM, while non-TOIs typically include MD and other metallic debris. At this time, only land-borne advanced EMI sensors are available.

6.3.5.1. Advanced EMI Surveys. Advanced EMI sensors designed specifically to classify anomalies as either TOIs or non-TOIs have been and are being developed and tested through the Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP). Live site demonstrations have shown these sensors to be significantly more successful at UXO classification than production-level DGM sensors, leading to a reduction in the number of anomalies that need to be dug at MRSs, while still removing the TOI. Advantages of advanced EMI sensors include those listed for DGM sensors, plus the following:

a. Provide the ability to collect data for a longer duration through the response decay.

b. Multiple axis target excitation and observation enable complete interrogation of the EMI response pattern from the subsurface metallic item.

c. More data enable greater ability to classify targets as either TOI or non-TOI.

d. Allow for less intrusive investigation, which lowers costs and results in less environmental and ecological impact.

6.3.5.2. Challenges. Challenges for performing investigations with advanced EMI technologies include those listed for DGM technologies. Additionally, most advanced EMI sensors are large and require the use of a vehicle to move the sensor from one target location to another, making them difficult to use within forested or high sloped areas; however, several man-portable systems are under development that may be used more easily in these difficult terrains in the future.

6.3.6. Underwater Geophysical Tools. Underwater geophysical sensors include EMI and magnetometers that have geophysical detection abilities similar to their land-based counterparts and generally are covered under the above sections. Marine geophysical tools also include sound navigation and ranging (sonar) technologies, which may have the ability to detect UXO lying proud on the water bottom floor (and sometimes below the sediment surface). Sonar technologies are more commonly used for imaging the bottom surface of the water body (e.g., sediment surface, boulders, felled trees) prior to underwater DGM surveys.

6.3.6.1. Bathymetric Technologies.

6.3.6.1.1. Advantages of Bathymetric Technologies.

- Are operated at a high altitude and are safe to operate as a reconnaissance method in uncertain bottom conditions.

- Generally are an efficient, high productivity method requiring minimal data processing.

- Are useful for developing detailed maps of bathymetry, sea bottom roughness and texture, and sediment type.

- Can be used to identify potential obstructions and hazards to underwater DGM and side-scan sonar (SSS) surveys where the instrument is towed at a low altitude.

- May be able to detect accumulations of munitions or conditions favorable for accumulation of munitions.

6.3.6.1.2. Challenges of Bathymetric Technologies.

- Lack the ability to resolve individual UXO lying proud on the sea bottom.

- Cannot penetrate the sediment bottom.

- Optical technologies (e.g., LIDAR) are dependent on clarity of the water.

6.3.6.2. Sediment Bottom Imaging Technologies.

6.3.6.2.1. Advantages of sediment bottom imaging technologies include the following:

- Can provide images of both the sediment surface and the underlying sediments.

- Can be used to identify potential obstructions and hazards to underwater UXO surveys.

- May be able to detect individual objects lying proud.

6.3.6.2.2. Challenges of sediment bottom imaging technologies include the following:

- Degree of bottom penetration and ability to resolve details are highly dependent upon the sediment type at the sea bottom.

- Sub-bottom Profiler (SBP) instruments trade off depth of penetration with ability to resolve details—lower frequencies penetrate more deeply, whereas higher frequencies are needed to resolve details.

- Require more data processing and interpretation than other sonic technologies.

- May lack ability to resolve individual UXO lying proud on the sea bottom in cluttered areas or where operating frequencies are too low.

- Only buried object scanning sonar (BOSS) has been shown to be able to image buried UXO under proper conditions. BOSS system is under development and is not commercially available.

6.3.7. Specific Types of Geophysical Instruments. Geophysical equipment also can be divided into two broad classes of instruments: passive and active. Passive instruments measure existing magnetic fields and the fluctuations within those fields. Passive instruments commonly used to detect anomalies potentially due to UXO include all types of magnetometers. Active instruments typically transmit an electromagnetic field and measure responses from the ground in the immediate vicinity of the detector. The active instruments most commonly used for UXO detection include EMI metal detectors. Table 6-1 presents many commonly used geophysical instruments for land investigations.

6.3.7.1. Magnetometers. Magnetometers were one of the first tools used for locating buried munitions. Most military munitions contain iron (ferromagnetic metal). When these types of UXO are in the presence of the Earth's magnetic field, a disturbance in the field is generated, which magnetometers can detect. Some magnetometers use two magnetic sensors (called gradiometers) configured to measure the difference over a fixed distance of the magnetic field rather than the absolute magnetic field. This configuration allows the gradiometer to perform with greater tolerance to cultural interference and improves detectability of some small TOIs. Since magnetometers respond to ferromagnetic metals, they are not be used to try to detect UXO that does not have a significant ferromagnetic metallic content. In addition, magnetometers are sensitive to many iron-bearing minerals and "hot rocks," which significantly increase the number of anomalies that need to be dug. Currently, three types of magnetometers are used most often to detect buried munitions.

a. Fluxgate Magnetometers. Fluxgate magnetometers are inexpensive, reliable, and rugged and have low energy consumption. Fluxgate magnetometers have long been a standard of EOD units as a quick, inexpensive field reconnaissance tool and are the least sensitive magnetometers in use in the MMRP (see Figure 6-1).

b. Optically Pumped Magnetometers. Optically pumped magnetometers (common commercial types include the cesium-vapor and potassium-vapor magnetometers) utilize digital technology and are more expensive to purchase than fluxgate instruments. However, their high sensitivity means they detect anomalies much deeper than fluxgate magnetometers (see Figure 6-1).

c. Proton precession magnetometers often are used in conjunction with optically pumped magnetometers. They provide information on the time varying changes in the Earth's magnetic field (diurnal variations) so that these changes can be removed from the magnetic field data. Proton precession magnetometers are less costly than optically pumped magnetometers and have less sensitivity and slower measurement rates but are suited for recording the relatively slow diurnal variations (see Figure 6-2)

Figure 6-1: Schonstedt GA-52 (left) Fluxgate Magnetometer and Geometrics G-858 (right) Optically Pumped Metal Detector

6.3.7.2. EMI Metal Detectors. EMI metal detectors work by either rapidly turning the current on and off or a sinusoidally varying current within a coil on the instrument. This varying current generates a changing primary magnetic field into the ground and induces electrical eddy currents in any nearby metallic objects. These currents then produce a secondary magnetic field that is measured by the instrument. They differ from magnetometers in that they are not limited to detecting ferrous items and can detect any conductive metal. In addition, EMI metal detectors usually are less affected by geologic sources than are magnetometers. There are two types: time domain electromagnetic detectors (TDEMI) and frequency domain electromagnetic detectors (FDEMI).

Figure 6-2: Geometrics G-856 Proton Precession Magnetometer

6.3.7.2.1. TDEMI. TDEMI instruments work by pulsing an electrical signal in the transmitter coils, which produce a primary magnetic field that induces an eddy current in the ground. The transmitting coil is turned off, and the secondary magnetic field produced from the resulting eddy current decay is then measured at predefined times. The eddy current decays much more slowly in conductive targets (such as metallic items) than in resistive materials (most soils). Such instruments provide a capability to locate all types of metallic military munitions. Because the signal from the buried metallic objects is recorded during a time when the signal from the instrument is off and the signal from the geology is attenuated, TDEMI instruments are one of the more reliable methods of detecting buried metallic items. Figure 6-3 presents examples of two TDEMI sensors. While TDEMI sensors have been proven to be effective in the detection of UXO at MRSs during production-level DGM surveys, they have inherent limitations that may decrease their effectiveness when applied to advanced classification using inversion. These limitations include the following:

- Analog smoothing of the EMI response during data acquisition to increase signal-to-noise ratio (SNR), which distorts the signal shape
- Limited measurement of the eddy decay cycle
- Positioning uncertainty on the order of centimeters degrades the parameter estimates (Bell, 2008) (see Section 6.6.5 for further discussion of anomaly parameters).

Figure 6-3: Vallon VMXC1 (left) and Geonics EM61-Mark 2 (MK2) (right) TDEMI Sensors

6.3.7.2.2. FDEMI. FDEMI instruments work by transmitting a sinusoidally varying electromagnetic (EM) signal at one or more frequencies through a transmitter coil. A separate receiver coil measures a signal that is a function of the primary signal and the induced currents in the subsurface. Depending on the size of the instrument and the frequencies generated, the system can detect metallic objects at varying depths and sizes. Because the signal from the buried metallic objects is recorded during a time when the primary signal is still on, these instruments measure the induced currents in the subsurface metallic objects differently than the TDEMI instruments. FDEMI instruments measure differences in the phase and amplitude between the received signal and the transmitted signal. The presence of subsurface metallic items results in changes in the measured parameters. The depth at which FDEMI instruments can detect metallic objects is dependent on antenna loop size and transmitter power. However, if careful measurements are made at multiple frequencies, this information often can provide diagnostic information on the type of buried metallic objects as well as the size of the object. Most commercial coin detectors are FDEMI instruments. Figure 6-4 presents an example of an FDEMI sensor.

Figure 6-4: Geophex GEM-3 FDEMI Sensor

6.3.7.2.3. Towed EMI arrays. Towed EMI arrays can increase the positioning accuracy over man-portable systems because of the fixed location of the sensors relative to each other; however, they also have a limited ability to excite and record the full EM response field when the transmitters are operated simultaneously because the primary response fields merge together and do not excite the object from different directions. If towed EMI arrays are pulsed sequentially, they can record the EM response from multiple directions; however, this reduces the rate at which data are collected (Bell, 2008). Figure 6-5 shows an example of a towed EMI array.

Figure 6-5: Example of a Towed TDEMI Array

6.3.7.3. Advanced EMI Sensors. Advanced EMI sensors have been developed through the SERDP and ESTCP specifically to detect and classify anomalies as either TOIs or non-TOIs. The advanced EMI sensors increase the effectiveness of UXO classification by overcoming the challenges that production-level EMI sensors have in performing TOI classification. In general, they measure the complete eddy current decay cycle and the complete EM response pattern via multi-axis target excitation and observation. These sensors sample the complete EM response pattern of objects by exciting and observing the item's EM response from all directions. The new sensors sample the full EM response pattern using multi-axis coil sensors (e.g., three orthogonal 1 m transmit coils and multiple receive coils) or via single axis coil arrays (e.g., 5x5 array of 35-centimeter [cm] transmit/receive coils). The goal of the advanced EMI sensors is to excite and measure the response from the object from all directions in order to extract the fundamental response functions by inverting the EMI data using the dipole response model for complete interrogation of the principal axis responses, or polarizabilities (Bell, 2008). Most advanced EMI sensors are TDEMI sensors; however, several FDEMI sensors are under development. Example systems include the Geometrics MetalMapper™, Time Domain Electromagnetic Multi-sensor Towed Array Detection System (TEMTADS), TEMTADS Man-Portable (MP) 2x2 Cart, Berkeley UXO Discriminator (BUD), Handheld BUD, All-Time EMI System (ALLTEM), and Man-Portable Vector (MPV) EMI Sensor. Of these systems, only the MetalMapper™ currently is available commercially. The following subsections provide a brief description of each of these systems; additional information on these systems as well as other systems currently in development can be obtained from the SERDP and ESTCP Web site (www.serdp-estcp.org).

6.3.7.3.1. The Geometrics MetalMapper™ system is designed for production-level surveys and cued target interrogation (see Figure 6-6). The system consists of three 1 m square transmitters and seven three-component 10 cm square receiver coils placed within the horizontal transmitter coil. The MetalMapper™ can collect data in survey mode like commercially available EM systems. For classification purposes, the MetalMapper™ is used in static mode, where the system is placed over targets identified in a production-level DGM survey. All three transmit coils are pulsed sequentially in the cued mode, and data are collected over a longer time window (e.g., up to 25 milliseconds [ms]) than production-level EMI sensors. The system can be placed on a sled or operated in a wheeled configuration but must be towed or mounted to a front-end tractor or other tow vehicle.

Figure 6-6: Geometrics MetalMapper™ Advanced EMI Sensor

6.3.7.3.2. The TEMTADS operates in a cued mode, with the system positioned over anomalies identified during production-level DGM surveys (see Figure 6-7). The system consists of a 5x5 array of 0.35 m x 0.35 m of transmitter/receiver coils oriented parallel to the ground surface. The transmitter coils are pulsed sequentially, with data collected at each receiver for each transmitted pulse. Data are collected up to 25 ms after the source current has been turned off.

Figure 6-7: Naval Research Laboratory (NRL) TEMTADS

6.3.7.3.3. The TEMTADS MP 2x2 Cart consists of a 2x2 array of four 35 cm x 35 cm square transmitter coils instead of the 5x5 array of the TEMTADS (see Figure 6-8). The instrument contains 8 cm, 3-component “cube” receivers. The system is man portable and, due to its size, can access areas with dense vegetation and steep terrain similar to what production-level EMI sensors commonly can access (Kingdon et al., 2012).

Figure 6-8: NRL TEMTADS MP 2x2 Cart

6.3.7.3.4. The BUD consists of three orthogonal transmitter coils and eight pairs of differenced receivers placed on the top and bottom of the system (see Figure 6-9). The BUD records the decay response curve up to 1.2 ms after the transmitted pulse has been turned off. The BUD can be used in survey mode but more typically is used in the cued mode, similar to the MetalMapper™. The BUD can be operated as a man-portable system; however, it is relatively large and the use of a tow vehicle greatly increases productivity.

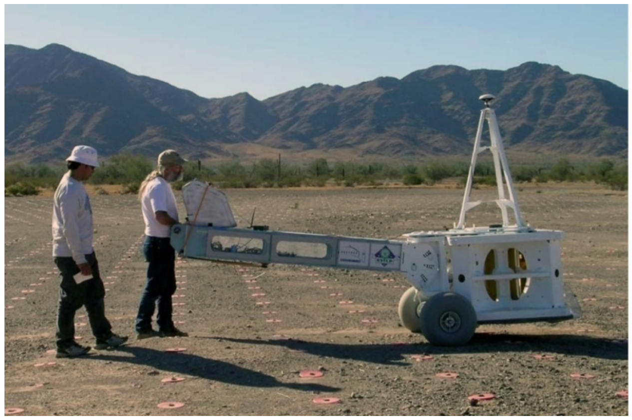

Figure 6-9: Lawrence Berkeley National Lab's BUD

6.3.7.3.5. The Handheld BUD is a lightweight, compact, portable version of the BUD that can be deployed under most site conditions, including areas of dense vegetation or steep terrain (where using the BUD or other large advanced EMI sensors that require a vehicle to move the sensor may be difficult) (see Figure 6-10). The Handheld BUD is a 14-inch cube that includes three orthogonal transmitters and 10 pairs of receivers and makes gradient measurements that significantly reduce the ambient and motions noise (Gasperikova, 2010).

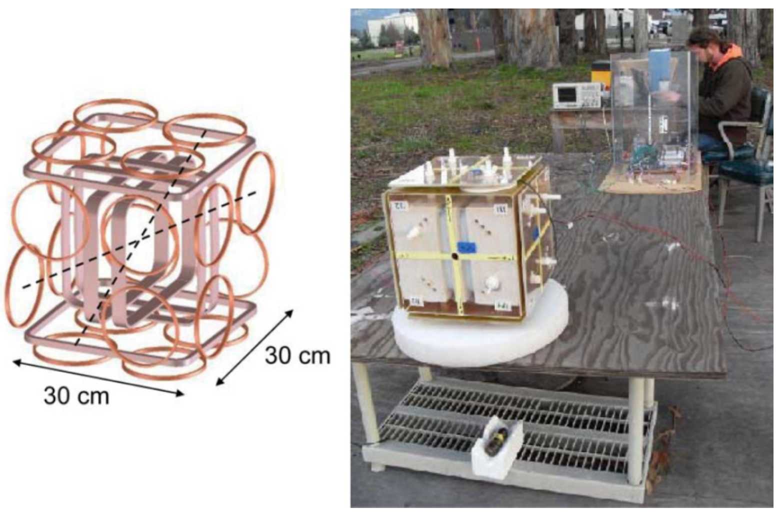


Figure 6-10: Lawrence Berkeley National Lab's Handheld BUD

6.3.7.3.6. The ALLTEM consists of three orthogonal 1 m transmit loops with 34 cm receiver loops located on the outside of the 1 m cube (see Figure 6-11). The system has 19 transmitter/receiver coil configurations. Data are collected in survey mode every approximately 15–20 cm at a vehicle speed of 0.5 m/second. The ALLTEM is unique among the advanced EMI instruments in that, instead of transmitting a signal that is recorded after the transmitted pulse is turned off, the ALLTEM transmits and receives at the same time. Like the TEMTADS and MetalMapper™, the system needs to be towed by a vehicle.

Figure 6-11: USGS's ALLTEM

6.3.7.3.7. The MPV EMI sensor is a handheld EMI sensor that consists of a transmitter, an array of three-dimensional receivers, a field-programmable control unit, and a portable local positioning system (see Figure 6-12). The MPV sensor is a 50 cm diameter circular loop transmitter and five multi-component receiver units, or cubes, consisting of 8 cm square coils. The MPV can be operated in a dynamic mode for target detection as well as in a static mode for target classification (Lhomme, 2011).

Figure 6-12: Sky Research's MPV EMI

6.3.7.4. Airborne Geophysical Sensors. Airborne geophysical sensors that have been successfully used on MR projects include included orthophotography, magnetic, EM, and LIDAR surveys. Potential airborne techniques include infrared, multi-spectral imaging, hyperspectral imaging, and synthetic aperture radio detection and ranging (radar) but require further validation testing using both helicopter and fixed-wing platforms. Airborne EMI and magnetometer technologies are largely the same as those used for ground-based investigations; however, the airborne investigations present more challenges (e.g., maintaining a constant height above the ground surface).

6.3.7.4.1. Aerial Photography. Historical and recent images taken from airborne cameras can be used to determine past and present conditions and identify range-related features at an MRS. Digital aerial photographs currently are more commonly used than film aerial photographs. Individual digital aerial photographs can be collected with an image density of approximately 4,000 x 4,000 pixels; merged into a mosaic image of the site; and orthorectified (ESTCP, 2008). The final size of image pixels depends on the number of camera-specific pixels and the flight altitude, but pixel sizes in the range of 10 cm to 20 cm can be achieved with reasonable combinations of flight speeds and elevations (ESTCP, 2008).Once the aerial photographic data type is collected, it is important to consider how processing will affect the accuracy. When performing digitization and/or orthorectification, the root mean square (RMS) error should be considered as a guide to determining the total accuracy of the layer.

6.3.7.4.2. LIDAR. LIDAR uses a pulsed laser directed downward from a relatively high-flying aircraft toward the ground surface. The ground surface elevation is determined by the two-way travel-time of the laser as well as the velocity in air. GPS and inertial navigation systems are used to precisely measure the position and orientation of the laser on the aircraft to allow for a more accurate calculation of the point of reflection of the laser signal from the ground, man-made structures, or vegetation (ESTCP, 2008). LIDAR can record the travel-times of multiple reflections from a single laser pulse, which increases the chance of sampling the ground surface through vegetation gaps. The number of reflections per square meter (or point densities) depend on the altitude, flight speeds, and laser repetition rates; point densities up to 4 to 6 per square meter can be achieved to allow for reliable detection of features on the order of 1 m at a survey rate of thousands of acres per day (ESTCP, 2008).

6.3.7.4.3. Multi-Spectral Imaging, Hyperspectral Imaging, and Infrared. These imaging techniques use wavelengths of light other than visible light to gather information about the ground. Multi-spectral and hyperspectral imaging use numerous different wavelengths, while Infrared uses the infrared spectrum. The data from each of the wavelengths can be plotted individually or in composite images to enhance ground features. Although not typically used in MR projects, they could be useful in detecting range-related features and metallic and non-metallic objects; however, it is unlikely that they can detect any but the largest UXO.

6.3.7.4.4. Synthetic Aperture Radar (SAR). Radar systems transmit electromagnetic, or radio, waves and then detect the reflection of the pulse at a radar system receiver. SAR uses the forward motion of the small radar array that is fixed to an airplane to synthesize a much larger array. The larger synthetic array effectively increases the resolution in the down-line direction and the SNR. By modifying the aperture length of the signal, the down-line resolution remains constant and is independent of frequency and range. This enables lower operating frequencies to be used, which increases the range of the sonar signal without negatively affecting the performance. The down-line resolution for SARs is approximately equal to one-half the actual length of the antenna (i.e., not the synthesized antenna length) and is independent of the antenna altitude. SAR may be capable of detecting large surface metal; however, few people have applied it to UXO detection, and it is unlikely that it will detect any but the largest of UXO.

6.3.7.5. Marine Geophysical Sensors. Underwater sensors that can be used on MR projects include geophysical sensors, bathymetric technologies, and sediment bottom imaging technologies. Underwater geophysical EMI and magnetometer technologies are largely the same as those used for land investigations; however, underwater investigations present more challenges, as discussed above. Geophysical sensors unique to the marine environment include bathymetric and sediment bottom imaging technologies.

6.3.7.5.1. Sonar. Active sonar is the process of emitting a pulse of sound waves (a "ping") into water and analyzing the time it takes for the sound waves to be reflected off the sediment surface or features lying on the sediment surface (e.g., logs, rocks, UXO lying proud) and return to a receiver (echo). The distance, or range, to the object is calculated using the measured time and the speed of sound in the water. The sound pulse can be either a narrow beam or a fan-shaped beam that covers the bottom as the vehicle moves through the water. Sonar recordings are used to create a raster image of the sediment bottom. Although some sonar technologies may have the capability to detect individual UXO lying proud on the sediment surface, in general, sonar systems cannot detect buried UXO. BOSS has been shown to have the capability to detect UXO below the sediment surface; however, the BOSS system is not commercially available and has not been validated at a standardized test site. It is likely that individual UXO would need to be relatively large in size for any sonar technology to be able to detect it lying proud or buried beneath the sediment surface. However, sonar technologies may present a good tool to use in a wide area assessment (WAA) type of investigation to identify potential disposal areas. The principal current use of sonar technologies is to provide information regarding the depth of the marine environment and information about potential obstructions to underwater magnetometer and/or EMI sensor surveys prior to the production-level underwater DGM investigation. Table 6-2 presents some of the more commonly used types of underwater UXO detection and sonar detectors. Figure 6-13 shows one example of a sonar sensor.


Figure 6-13: Example of a Sonar Sensor

6.3.7.5.1.1. Multibeam echo sounder (MBES) systems are useful in mapping bathymetry (i.e., topographical variations of the sediment surface), identifying metallic debris, identifying obstructions that could interfere with low altitude geophysical sensors (Funk et al., 2011), and dive operations (see Figure 6-14). The multibeam sonar's acoustic pulses are transmitted in a fan-shaped pattern and reflect back from the seafloor or items on the seafloor. The multibeam echo sounder's multiple transmitters and larger swath width cover significantly more area of the sediment surface than traditional simple echo sounders, which transmit only a single acoustic wave. The multibeam reflections are measured from different angles across the swath. The size, shape, and distance to features on the seafloor can be determined by analyzing the angles and two-way travel times of each beam. Factors that affect the multibeam bathymetric resolution include the speed of sound in water, sonar frequency, beam width and angle, water depth, ping rate, and vessel speed (Funk et al., 2011). Physical properties of the seafloor affect the strength of the return signal of the multibeam pulse and can assist in characterizing features identified in the multibeam soundings. Hard materials (e.g., metals, boulders, gravel, volcanic rock) are very efficient at reflecting the multibeam pulses, while fine-grained sediments (e.g., silts, clays) absorb more of the acoustic energy and, therefore, have much weaker reflected signal strength. Data analysis software can be used to delineate areas with similar seafloor physical and geologic properties (Funk et al., 2011).

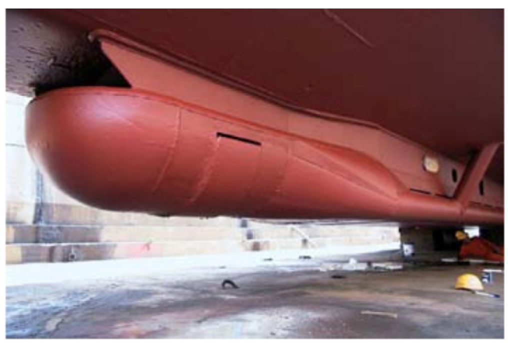

Figure 6-14: Example of an MBES Sensor

6.3.7.5.1.2. SSS systems are a special type of sonar that is used to create an image of the sediment surface and any objects lying on top of it (see Figure 6-15). SSS transmits a narrow, fan-shaped acoustic pulse, or ping, perpendicular to the direction of travel. As the pulse radiates away from the sonar unit, some of the sound energy is reflected off the seafloor and other objects back toward the SSS system. The reflected energy is known as backscatter, which is the reflection of waves, particles, or signals back to the direction they came from. The travel time and signal strength, or amplitude, of the reflected acoustic wave are analyzed to create a raster image of the seafloor. The transmitted beams of the SSS have a low grazing angle (i.e., they are directed horizontally away from the sonar versus being directed beneath the sonar). This results in distinctive shadows being cast behind objects on the seafloor, which helps make smaller objects more visible and provides greater detail on larger objects. Although SSS doesn't measure feature depths, the resulting images can provide reasonable size estimates for features. SSS often can provide high enough resolution to enable the identification of features on the sediment surface and within the water column and is efficient at finding small features. SSS data resolution, like multibeam echo sounding, is a function of the operating frequency of the sonar, number of beams, beam width, pulse rate, beam angle, and vessel speed (Funk et al., 2011). SSS can provide detailed images of the seafloor and seafloor geomorphology and may detect UXO that lay proud of the bottom; however, the ability to determine the nature of the source is highly dependent on the size of the target and its distance from the sonar. Previous studies indicate that bright spots (strong reflections) in SSS data may be used to identify the location of metallic objects; however, these bright spots are unlikely to be differentiated from other sonar bright spots without the aid of DGM data (Funk et al., 2011).

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Table 6-1: Land and Airborne Geophysical Detection Technologies (as of June 2011)

| **Technology** | **Effectiveness**[a] | **Implementability**[a] | **Cost** | **Representative Systems**[b] | **Notes** |
|---|---|---|---|---|---|
| TDEMI Metal Detectors:<br><br>Production EMI | **High:**<br>Standard detector for EM. High industry familiarization. Detects ferrous and non-ferrous metallic objects. | **Medium to High**:<br>Typically utilizes 1 m wide by 0.5 m or 1 m for transmitter and receiver coils, but alternate sizes are available. Can be used in most traversable terrain. Most commonly used instrument is widely available. Processing and interpretation are relatively straightforward. Classification possibilities exist for multi-channel systems. | **Average**<br>Average in typical terrain. Below average when arrays of multiple detectors are used. | Geonics EM61<br>Geonics EM 61-hh<br>Geonics EM61-MK2<br>Geonics EM61-MK2 HP<br>Geonics EM63<br>G-tek/GAP TM5-EMU<br>Schiebel AN PSS-12<br>Vallon VMH3 | Digital signal should be co-registered with positional data for best results. Detection depths are highly dependent on coil size (number of turns and wire resistance are important) and transmitter power. |
| TDEMI Metal Detectors:<br><br>Advanced EMI | **High:**<br>Some may be used in production mode to detect subsurface metallic objects, and all can collect static measurements over a target location to record entire EMI response pattern. Greatest ability of all sensors for the classification of anomalies as either TOI or non-TOI. Detect both ferrous and non-ferrous metallic objects. | **Low to Medium:**<br>MetalMapper™, TEMTADS, and ALLTEM require the use of a vehicle to tow the sensors to the location of an anomaly. Other sensors are man portable. One-meter-wide coil (or greater) limits accessibility in forested or steeply sloped areas; however, man-portable systems have the same accessibility as production-level EMI sensors. | **Average**<br>Use of the advanced systems often represents additional surveying and processing costs, which may be largely offset by the decrease in the intrusive investigation costs. | ALLTEM<br>BUD<br>Handheld BUD<br>MetalMapper™<br>MPV EMI<br>TEMTADS<br>TEMTADS MP 2x2 Cart | Currently, only the MetalMapper™ is commercially available. All other systems are in development and testing. |

| **Technology** | **Effectiveness**[a] | **Implementability**[a] | **Cost** | **Representative Systems**[b] | **Notes** |
|---|---|---|---|---|---|
| FDEMI Metal Detectors | **Low-Medium**:<br>These systems have not been the primary detector in any highly ranked UXO detection systems. However, experience demonstrates capability of detecting small items and potential for improved classification information with multi-frequency digital units. Not good for detecting deeply buried, single items. High industry familiarization. Detects both ferrous and non-ferrous metallic objects. | **High:**<br>Handheld detectors are light and compact. Can be used in any traversable terrain. Widely available from a variety of sources. Classification possibilities exist among some multi-channel systems. | **Lower** than average cost in typical terrain, with the exception of the Geophex GEM3, which is average | Fisher 1266X<br>Foerster Minex<br>Garrett<br>Geophex GEM3<br>Minelabs Explorer II<br>White's All-Metals Detector | Analog output not usually co-registered with positional data. Digital output should be co-registered with positional data. |
| Flux-Gate Magnetometers | **Medium:**<br>Have been used as the primary detector in traditional mag-and-flag and mag-and-dig operations. High industry familiarization. Only detects ferrous objects. | **High:**<br>Light and compact. Can be used in any traversable terrain. Widely available from a variety of sources. | **Lower** than average on most terrain | Chicago Steel Tape (magna-trak 102)<br>Ebinger MAGNEX 120 LW<br>Foerster FEREX 4.032<br>Foerster FEREX 4.032 DLG Schonstedt 52-CX<br>Schonstedt 72-CX<br>Vallon EL 1302D1 or 1303D | Analog output not usually co-registered with positional data |

| Technology | Effectiveness[a] | Implementability[a] | Cost | Representative Systems[b] | Notes |
|---|---|---|---|---|---|
| Optically Pumped Magnetometers | **High:** Standard detector for digital magnetic data collection for UXO detection. High industry familiarization. Only detects ferrous objects. | **Medium to High:** Relatively light and compact and can be used easily in open areas. Can be used in most traversable terrain. Widely available from a variety of sources. Processing and interpretation require trained specialists. Classification possibilities are limited to magnetic susceptibility / magnetic moment estimates and depth estimates. Detection capabilities are negatively influenced by iron-bearing soils. | **Average** in typical terrain. Much below average when arrays of multiple detectors are used. | Gem Systems GSMP-40<br>Geometrics G-858<br>Geometrics G-822<br>Scintrex Smart Mag | Digital signal should be co-registered with positional data for best results. |
| Cryogenic Magnetometers | **High:** Research instrument that has promise for improving detection depth. Low industry familiarization. Detects ferrous objects only. | **Low:** Research instrument currently undergoing testing and modifications and only useful in open, level terrain. Minimal availability and still requires validation testing before being implemented on UXO field surveys. | **Much Higher** than average. Very low availability. | | Limited commercial availability |
| Sub Audio Magnetics | **Medium:** Detects both ferrous and non-ferrous metallic objects. Capable tool for detection of deep UXO. Detects deepest UXO. Low industry familiarization. | **Low:** High data processing requirements. Available from one source. High power requirements. Longer than average setup times. | **Higher** than average. Very low availability. | GAP Geophysics PTY - SAM | Not commercially available |

| Technology | Effectiveness[a] | Implementability[a] | Cost | Representative Systems[b] | Notes |
|---|---|---|---|---|---|
| Magnetometer-Electromagnetic Detection Dual Sensor Systems | **Higher:** Detects both ferrous and non-ferrous metallic objects. Medium industry familiarization. Higher potential for classification than individual EM or magnetic sensor. | **Medium:** High data processing requirements. Available from few sources. | **Higher** than average. Lower costs using a towed array platform. | ERDC EM61HH & G-822<br>SAIC MSEMS (man-portable)<br>SAIC STOLS / VSEMS (vehicular) | Commercially available |
| Airborne Multi- or Hyper-spectral Imagery and Infrared Sensors | **Low to Medium**: Detects both metallic and non-metallic objects. Only detects largest UXO. Requires line of sight. Low industry familiarization. Effectiveness increases when used for WAA in conjunction with other airborne technologies. | **Medium:** Requires aircraft and an experienced pilot. Substantial data processing and management requirements. Available from few sources. | **Low-Medium per acre** when surveying large areas (> 500 acres). Additional costs include aircraft rental/purchase and maintenance costs and processing costs. | | Active area of growth for application to the UXO problem. |
| Airborne SAR | **Low:** Detects large surface metallic objects. Requires line of sight. Medium industry familiarization. | **Low:** Requires a specialized aircraft and an experienced pilot. Unique and substantial data processing and management requirements. Available from very few sources. | **Higher** than average due to aircraft O&M costs and data processing and validation costs. | | Few have applied these technologies to the UXO problem. |
| Airborne LIDAR | **Low to High**: Detects both metallic and non-metallic large surface objects. High industry familiarization. Effectiveness increases when used for WAA in conjunction with other airborne technologies. | **Medium:** Requires aircraft and an experienced pilot. Poor implementability when vegetation obscures ground features and it cannot image the ground surface. Not used to locate individual TOIs. Substantial data processing and management requirements. Available from increasing number of sources. | **Low-Medium per acre** when surveying large areas (> 500 acres). Additional costs include aircraft rental/purchase and maintenance costs and processing costs. | | Active area of growth for application to the UXO problem. |

| Technology | Effectiveness[a] | Implementability[a] | Cost | Representative Systems[b] | Notes |
|---|---|---|---|---|---|
| Ground Penetrating Radar (GPR) | **Low**:<br>Many mine detection systems use GPR as one detector; however, has very low success rates as a stand-alone UXO detection system. Detects both metallic and non-metallic objects. Susceptible to variable environmental/ geological conditions. Medium industry familiarization. | **Low**:<br>Large, bulky, requires trained operator, and is slow to operate. Difficult to use in any but the easiest terrain. Widely available from a variety of sources. | **Higher** than average. Systems are slow and required survey coverage is expensive. | GSSI SIR2, SIR3, SIR8, SIR10<br>RAMAC Software<br>Sensors & Software PulseEKKO Pro | Data output is usually viewed in transects not maps. |

a Data positioning is a significant factor that can substantially affect the success of any geophysical technology. The effectiveness and implementability of data positioning technologies also must be considered when evaluating a geophysical technology.

b The government does not express nor imply preference for any of the mentioned systems but merely provides these examples for informational purposes only.

Table 6-2: Marine Geophysical Detection Technologies (as of June 2011; modified from Schwartz and Brandenburg, 2009)

| Technology | | Effectiveness/Special Considerations[1] | Implementability[a] | Relative Cost | Representative Systems[b] |
|---|---|---|---|---|---|
| Metal Detection | TDEMI | **High:**<br>Typical commercial off-the-shelf (COTS) TDEMI systems are well suited for use in shallow underwater environments. Array platforms may be hard to control. Depth of detection can be increased minimally by increasing power output of system. Can detect small and large items. | **High:**<br>Detects both ferrous and non-ferrous metallic objects. | **Low:**<br>Relatively low compared to other systems. | Ebinger UWEX 700 series<br>Geonics EM61S-MK2 |

| Technology | | Effectiveness/Special Considerations[1] | Implementability[a] | Relative Cost | Representative Systems[b] |
|---|---|---|---|---|---|
| | FDEMI | **Medium:**<br>Requires divers that are trained in the use of FDEMI technology. Bottom time of diver must be taken into consideration. Can detect small and large items, but detection depth is limited by small coil sizes and low power transmitters. Prototype towed array detection of munitions has been demonstrated. | **Medium:**<br>Detects both ferrous and non-ferrous metallic objects. | **Medium to High:**<br>Higher costs derive from man-hours required for trained divers. | DetectorPro Headhunter Diver<br>Fisher Pulse 8X<br>Fisher 1280-X Underwater<br>Garret Infinium LS<br>Garrett Sea Hunter Mark II<br>Minelab Excalibur 1000 |
| | Fluxgate Magnetometer | **Medium:**<br>Fluxgate magnetometers are typically reliable, rugged, have low energy consumption, and are less susceptible to errors. Can detect small and large items. | **High:**<br>Detects ferrous metallic objects | **Low** | Ebinger MAGNEX 120 LW<br>Foerster FEREX 4.032<br>Foerster FEREX 4.032 DLG<br>Kokkola Dredging Co. mag array<br>Vallon-Etl303D2- |
| Metal Detection | Optically Pumped (Atomic Vapor) Magnetometer | **High:**<br>High level of industry familiarization for optically pumped magnetometers with COTS underwater units available. Can detect small and large items. Higher sensitivity (versus fluxgate) - 40% increase in detection range for given size magnetic target. | **High:**<br>Detects ferrous metallic objects | **Medium to High:**<br>Higher cost derives from autonomous vehicle (AUV)<br>or remotely operated vehicle (ROV) use | G880 Cesium Marine Deep Tow Magnetometer<br>GTK UW mag array |
| | Proton Precession Magnetometer | **Medium:**<br>Low level of industry familiarization for proton magnetometer utilization for munitions work. Sampling rates must be factored into tow speed. Can detect small and large items. | **High:**<br>Detects ferrous metallic objects. | **Low** | Discover Underwater Proton Magnetometer<br>JW Fishers Proton 4 MX500 Digital Magnetometer |

| Technology | | Effectiveness/Special Considerations[1] | Implementability[a] | Relative Cost | Representative Systems[b] |
|---|---|---|---|---|---|
| | Magnetometer-Electromagnetic Detection Dual Sensor Systems | **High** (for detection):<br>System integration and timing of signals/readings need to be carefully maintained. Can detect small and large items. Prototype underwater system still in development. Currently limited to about 10 feet of water depth. | **High:**<br>Detects both ferrous and non-ferrous metallic objects | **Medium** | USEMS |
| Sonar | SSS | **Low** (for UXO detection), **High** (for visualization of water body floor surface):<br>Visualizes shapes of both metallic and non-metallic objects. Will not identify munitions covered by sediment, plant growth, or rock. Can detect large items, but actual capabilities and limitations for detecting and classifying munitions are unknown. Medium-low industry familiarization. | **Medium** (for detection), **High** (for visualization):<br>Creates image of large areas of the sea floor, but munitions must be on surface or proud and uncluttered by nearby environmental factors (such as coral, rocks, and vegetation). Requires boat, trained operator, experienced field driver crew, and low vegetation; calm water may be needed. Vegetation can hinder acoustic signal propagation. | **Average** for marine investigations | EdgeTech DF-1000<br>Fishers SSS-100k/l600K<br>GeoAcoustics<br>Klein 3000 Series SportScan<br>Klein 5500<br>Marine Sonic Technologies<br>Tritech SeaKing Towfish |
| Sonar | MBES | **Low** (for detection), **High** (for bathymetry):<br>Theoretically can provide enough detail to identify munitions on or proud of the water bottom, but capabilities, interferences, and limitations are untested and unknown. | **High:**<br>Produces high-resolution bathymetry data throughout the survey area. | **Low to Medium** | Kongsberg EM 3002<br>Kongsberg EM 2000<br>RESON SeaBAT |

| Technology | | Effectiveness/Special Considerations[1] | Implementability[a] | Relative Cost | Representative Systems[b] |
|---|---|---|---|---|---|
| | High-resolution, portable SONAR systems | **Low** (for detection), **High** (for imaging seafloor):<br>Can assist ROV/ AUV and divers with identification of munitions in turbid waters. Specific models can be used up to 3000 m deep. Can detect small and large items depending on system used and distance from object. Object must be on or proud of the sea floor. | **High:**<br>Produces high-resolution sonar imagery even in areas of high turbidity. | **Medium** | BlueView<br>Dual Frequency Identification Sonar |
| | SBP | **Low** (for detection), **High** (for sediment imaging):<br>High-resolution sub-bottom systems have been used to identify buried objects but not likely to detect munitions unless fairly large. Not economical because 100% coverage would be needed; could be deployed with other 100% coverage mapping. | **High:**<br>Allows for the identification and measurement of various sediment layers that exist below the sediment/water interface. | **Medium to High** | Bathy 2010<br>Geo Chirp<br>Geo Chirp 3-D<br>Imagenex OF 1030 |
| Sonar | Synthetic aperture sonar (SAS) | **Medium** (detection), **High** (imaging seafloor):<br>SAS technology is still relatively new. Munitions detection capability versus proud targets is promising, but limited demonstrations. Low-frequency prototype SAS has demonstrated detection of partially buried objects. | **Medium to High:**<br>Synthetic aperture sonar moves sonar along a line and illuminates the same spot on the seafloor with several pings. | **Medium** | Kongsberg HISAS 1030 |
| | BOSS | **Medium** (for detection):<br>Known systems are still experimental; currently demonstrated detection capabilities show very consistent detection through 30 cm of sand. Classification capabilities unknown | **High:**<br>BOSS generates images of objects buried in underwater sediments. | **Medium to High** | CHIRP Lab SAS 40 Channel<br>CHIRP Lab 252 Channel |

a Data positioning is a significant factor that can substantially affect the success of any geophysical technology. The effectiveness and implementability of data positioning technologies also must be considered when evaluating a geophysical technology.

b The government does not express nor imply preference for any of the mentioned systems, but merely provides these examples for informational purposes only.


Figure 6-15: Example of an SSS Sensor

6.3.7.5.1.3. SAS is similar to SSS except that it uses multiple pulses to create a large synthetic array or aperture (see Figure 6-16) (Hansen, 2011). SAS uses the forward motion of a small sonar array to synthesize a much larger array. The larger synthetic array effectively increases the resolution in the down-line direction and the SNR. By modifying the aperture length of the signal, the down-line resolution remains constant and is independent of frequency and range. This enables lower operating frequencies to be used, which increases the range of the sonar signal without negatively affecting the performance. SAS systems also have the advantage of a wider field of view, which results in a larger angular response from objects on the seafloor. This reduces the possibility of missing potential targets on the seafloor (Fernandez et al., 2003). The increased resolution of SAS may make it suitable for detection of UXO that are lying proud on the sediment surface. Recent sensor response modeling research indicates that that SAS can indeed detect large metal objects; however, the simulated SAS was unable to detect an 81-millimeter (mm) mortar (Lim, 2008). Other studies indicate that SAS can detect large munitions (e.g., 155 mm projectiles) lying proud on the sediment surface, but these studies didn't include smaller munitions (Williams et. al., 2010).


Figure 6-16: Example of an SAS Sensor

6.3.7.5.1.4. BOSS is wideband sonar that generates three-dimensional imagery of buried, partially buried, and proud targets (see Figure 6-17). It is a type of SAS system that uses hydrophone receiver arrays to transmit an omnidirectional acoustic pulse and to record the energy backscatter from both the sediment surface and sediment layers. The recorded backscatter is focused via image processing to generate images of the top and side views of buried objects. Images of surface and subsurface objects are created using real apertures in the cross track direction and synthetic apertures in the along-track direction. Focusing of the sonar energy in the near field creates plan view and cross sectional images of partially and fully buried objects. BOSS systems have shown the ability to detect ordnance buried below the sediment surface (Kerry, 2010). No validation studies have been performed at this time, however, so the system's UXO detection capabilities and limitations are unknown. Some studies indicate that determination of the burial depth is possible, although further testing with UXO is required.

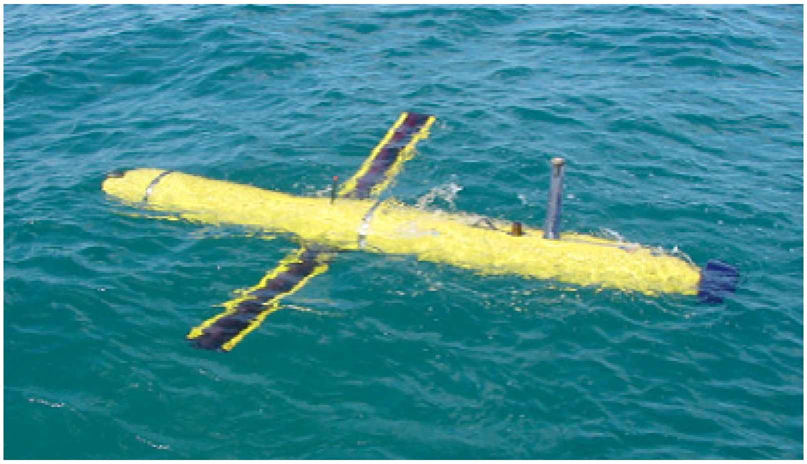


Figure 6-17: Example of a BOSS Sensor

6.3.7.5.2. LIDAR. LIDAR is more commonly used in terrestrial investigations for WAA of range-related features but can be used in underwater investigations to map bathymetry of a water body. LIDAR systems transmit laser light pulses into the atmosphere and record the energy that is reflected off of objects, both on the surface (land and water surface) and from the bottom of the water body. Bathymetric LIDAR receives two frequency pulses, one frequency is reflected from the surface of the water body, and the other is reflected from the bottom of the water body. Variations in the travel time between the two pulses then are used to determine the depth of the water body. If the water body is clear, bathymetric LIDAR can reach up to 50 m of water depth (NOAA, 2011). Decreasing levels of water clarity decrease the effective depth of the bathymetric LIDAR system. Bathymetric LIDAR may be more expensive than MBES for many sites but is likely a better choice for determining bathymetry in areas with rugged shorelines that could prevent surface vessels from operating effectively and/or safely without prior, detailed knowledge of the water depths.

6.3.7.5.3. SBP. Sub-bottom profilers function similarly to echo sounders in that they transmit a sound pulse, or ping, that is recorded after the sound pulse has reflected back to the sensor (see Figure 6-18). However, sub-bottom profilers transmit the sound pulse vertically downward and are seismic reflection, in principal. When the pulse encounters boundaries between two layers that have different acoustic properties (i.e., acoustic impedance), a portion of the pulse is reflected and a portion is transmitted through the boundary and is reflected when it encounters another, deeper boundary. The thickness and density of sediment layers can be estimated using the travel time and reflected amplitude strength (Funk et al., 2011). Sub-bottom profilers can be used to determine the different sediment layers and areas with concentrated munitions; however, they are unlikely to detect individual UXO. Sub-bottom profiler signal frequency affects the ability to identify sediment layers. Higher frequency signals provide greater resolution than lower frequency signals; however, the higher frequency signals attenuate more rapidly and won't penetrate as deep as the lower frequency signals.


Figure 6-18: Example of an SBP

6.3.7.5.4. Optical Systems. There are two types of underwater optical systems that can be used for WAA in underwater environments: camera (video and still) and laser line-scan. Cameras use ambient or strobe light to capture a photograph of the water bottom, analogous to orthophotography. Laser line-scan systems record the time of return and reflected intensity from a laser pulse that is used to create raster images of the sediment bottom. Similar to LIDAR, laser line-scan systems measure range to the bottom, obtain a measure of reflectance from every laser pulse, and produce an image built up from thousands of successive laser pulses (ITRC, 2010). Like orthophotography, underwater optical sensors provide an image of the bottom surface. They have no ability to penetrate the bottom, and the usefulness for WAA can be degraded by vegetation and the turbidity of the water. Heavy vegetation or high turbidity levels may make it difficult to recognize targets of interest in an underwater photograph; the three-dimensional information available from a laser line-scan image may help with this problem. At present, laser line-scan systems are not common in the commercial market (ITRC, 2010).

6.4. Positioning and Navigation Techniques.

6.4.1. The precision, and often the accuracy, of measured geophysical data positions are critical components of the geophysics products. Because the ultimate goal of magnetometer and EM surveys is to reproduce the actual potential field that exists over a given site, the success of the surveys relies heavily on how well the geophysical system can accurately and precisely locate where each measurement was actually taken.

6.4.2. We define precision as how well a positioning system can register where one measurement was taken with respect to all other neighboring measurements that were taken (see Figure 6-19). We define accuracy as how well a positioning system can register where measurements were taken with respect to a geographic coordinate system. This term is used to define how close reported coordinates are to the actual, physical locations on the Earth where the measurements were taken. In most cases, the terms precision and accuracy need not be differentiated and only the term accuracy need be used. However, there could be some cases where the accuracy of a group of measurements is not critical to a project's objectives but the precision is (for example, during site characterization or in advanced classification).

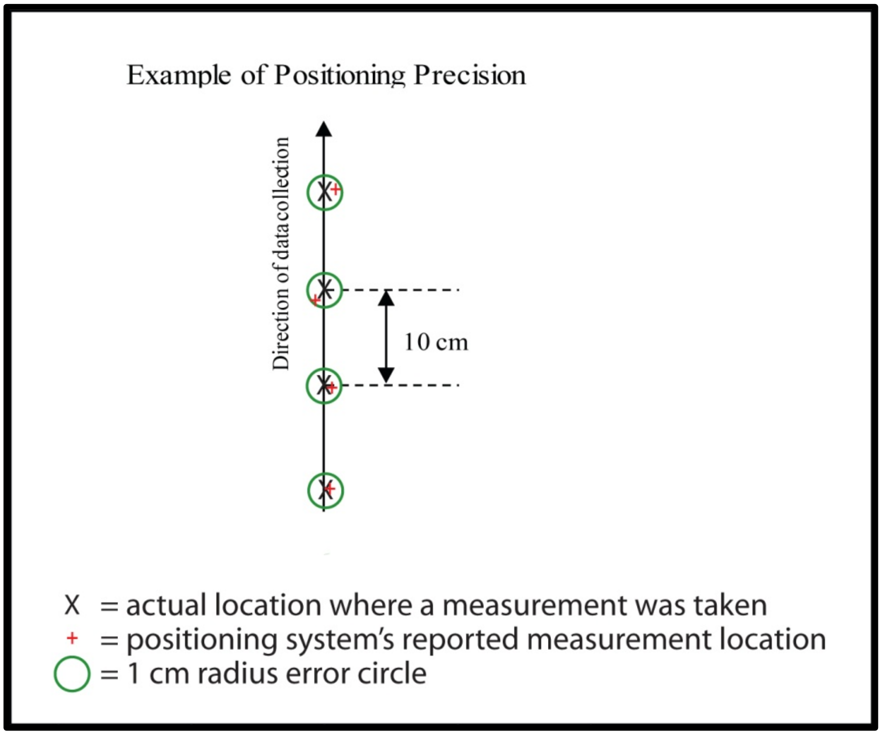



Figure 6-19: Example of Positioning Precision

6.4.3. There are three levels of accuracy needed for geophysics to support the MMRP:

6.4.3.1. Screening level to determine areas of interest as implemented by airborne sensors or characterization efforts by ground based sensors by corridors, transects, or meandering pathways. Typical accuracies will be sub-meter to tens of meters, and precision typically will be sub-meter.

6.4.3.2. Area mapping as performed by man-portable and towed arrays. Typical accuracies will be sub-meter to several decimeters, and precision will be centimeter to decimeter.

6.4.3.3. Interrogation, where highly accurate and dense data are acquired to interrogate and then, by post processing the accurate layered data, classify a previously located target. Typical accuracies and precisions will be centimeter to sub-decimeter.

6.4.4. The remainder of this subchapter describes various positioning options for geophysical surveys.

6.4.4.1. Line and fiducial positioning (also referred to as line and station, conventional positioning, or straight-line profiling) is the simplest form of geophysical data positioning and has been in use for the longest period of time. The premise of line and fiducial positioning is that the geophysical instruments are operated in straight lines between fixed, known locations. Often, a rectangular coordinate system is used to define a local Cartesian coordinate system over a given area. These areas usually are called grids, and each grid is uniquely identified. The normal convention is to assign Cartesian coordinates of zero east (or zero “x”) and zero north (or zero “y”) to the southwestern-most corner of a grid. Grid dimensions can be tens of meters to several hundred meters on a side. The geophysical measurement positions in the grid are calculated by collecting data in a straight line from one known location in the grid to another known location in the grid. Most often, fiberglass measuring tapes are stretched along either the southern and northern edges of the grid or the western and eastern edges of the grid, from one grid corner to the next. In this manner, the distance gradations on the fiberglass tapes provide the known locations along the grid boundaries, and the geophysical operator can traverse the grid from one known point to another with relative ease. As the operator traverses the grid to collect data, the geophysical instrumentation is set up to collect data either at regular intervals in time (time-based triggering) or at regular intervals in distance by use of an odometer trigger (distance-based triggering). Note that these are triggering mechanisms only and are used to cause the instruments to take and record a measurement. Common time-based triggering intervals are 0.1 sec (10 hertz [Hz] measurement rate) and common distance triggering intervals are 20 cm. The data logging system is configured to capture the starting location, the direction of travel, the measurement triggering parameters, and any other instrument-specific information that is needed to calculate positions of individual geophysical measurements that are recorded. Since the distance traveled along each survey line is known, all measurements recorded along a linear segment can be equally spaced between the known points between which the data were collected. Often, intermediate known points, or fiducial marker lines, also will be established within a grid by stretching additional fiberglass measuring tapes parallel to, and at equal intervals between, the fiberglass tapes placed along the grid’s boundary. These intermediate markers are used by the operators to help maintain straight survey lines and to allow them to make fiducial marks at known points within the data stream. Data that are marked with a fiducial mark (often a special character appearing in a marker column within the data stream) signify the sensor was at a known location at the time that measurement was made. Figure 6-20 illustrates a grid setup over a 50 m by 50 m area. In this example, there is one intermediate fiducial line setup between the southern and northern grid boundaries, and data are to be collected along parallel north- and south-oriented lines. The arrows along the lines indicate the planned direction of travel along each line. Referring to Figure 6-20, data are collected in the following manner:

a. The operator aligns the equipment along the line to be traversed and enters line-specific coordinate and triggering information into the data logger.

b. The operator places the sensor directly over the marker along the grid boundary and begins collecting data along the line immediately as he/she begins moving. Or the operator places the sensor outside of the area to be surveyed and begins moving along the line to be traversed. As the sensor crosses over the grid boundary, the operator immediately begins data collection.

c. The operator maintains a straight-line traverse along the line to be surveyed and uses a toggle switch or other momentary switch to enter fiducial marks when the sensor moves directly over a fiducial line. If a time-based triggering system is being used, the operator must maintain a constant pace between all known locations (i.e., between the start of line location and the first fiducial mark, the first and next fiducial mark, etc., and the last fiducial mark and the end of line location). If distance-based triggering is being used, then the operator need not maintain a constant pace, but he/she must maintain forward travel at all times.

d. When the sensor passes over the boundary that defines the end of the line, the operator immediately ceases collecting data.

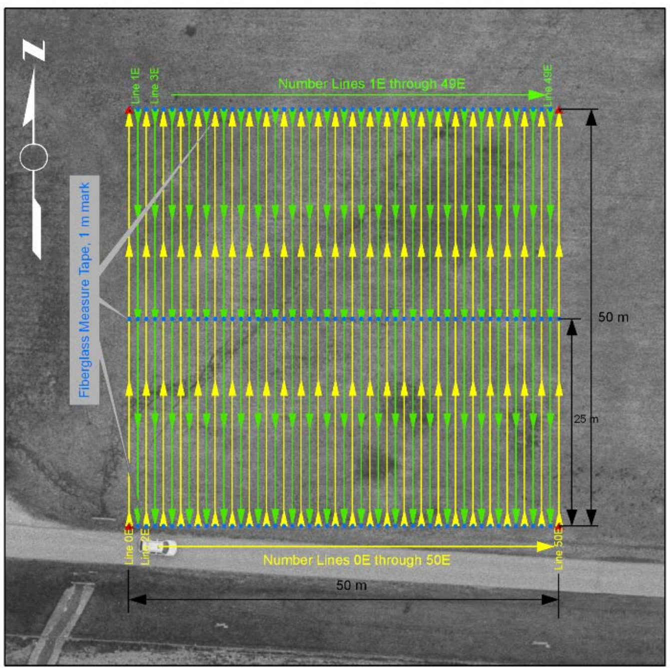



Figure 6-20: Line and Fiducial Grid Setup

6.4.4.2. Figure 6-21 illustrates a typical data stream of EM61-MK2 data collected using distance-based triggering. This figure is provided to help the reader understand how data are collected and what the collected data look like when the line and fiducial method is used. In this example, the line number (e.g., Line 0) corresponds to the Easting, or x coordinate, along which data were collected. Data were collected in north-south directions.

6.4.4.3. Differential GPS (DGPS) and real-time kinematic (RTK) DGPS is now the primary navigational method in MMRP geophysical surveys. Software for most geophysical systems now includes a means of integrating GPS positions with geophysical data. GPS equipment varies drastically in price and quality; therefore, a minimum standard for equipment to be used in DGM surveys must be defined. The level of accuracy required for a specific project depends on the goals. For characterization surveys, accuracy within 10 m may be acceptable, while a more detailed investigation may have more demanding requirements.

```
/Example Data Set
/Intrument: EM61-MK2
/Coordinate System: Local, units: feet
/Column Names follow:
/NORTH,EAST,STD-4-1,STD-4-2,STD-4-3,STD-4-4,TIME
LINE  0.00
      0.00        0.00     67.97      25.89      -1.21      -3.10  15:27:41.180
      0.66        0.00     70.69      32.47       6.74      -3.33  15:27:41.871
      1.32        0.00     78.41      38.75      12.41      -1.14  15:27:42.283
      1.98        0.00     94.97      49.79      17.93       1.66  15:27:42.642
       .           .         .          .          .          .     .
       .           .         .          .          .          .     .
       .           .         .          .          .          .     .
    162.96        0.00      4.14     -17.45     -23.32     -17.38  15:28:32.924
    163.65        0.00      5.87     -17.90     -24.07     -16.55  15:28:33.800
    164.32        0.00      6.47     -16.02     -22.79     -16.63  15:28:34.599
    165.00        0.00      7.90     -14.14     -20.99     -16.93  15:28:36.578
LINE  2.50
    165.00        2.50      8.02     -16.41     -23.82     -16.33  15:29:31.769
    164.32        2.50     12.85     -12.55     -21.40     -16.33  15:29:32.192
    163.64        2.50     18.75      -8.39     -19.58     -15.65  15:29:32.446
    162.97        2.50     23.44      -5.29     -18.30     -14.82  15:29:32.698
       .           .         .          .          .          .     .
       .           .         .          .          .          .     .
       .           .         .          .          .          .     .
      3.31        2.50    218.64     136.74      72.50      28.05  15:30:26.182
      2.65        2.50    187.37     114.18      61.60      21.81  15:30:26.434
      1.98        2.50    153.83      89.67      47.39      14.82  15:30:26.741
      1.33        2.50    126.84      69.96      33.55       9.33  15:30:27.033
      0.66        2.50    100.36      53.34      22.72       4.29  15:30:27.338
      0.00        2.50     80.51      38.52      12.41      -0.98  15:30:27.658
LINE  5.00
      0.00        5.00     18.51       6.75      -1.21      -0.91  15:32:04.485
      0.67        5.00     60.17      25.42       0.61      -4.10  15:32:04.964
      1.33        5.00     77.43      36.44       9.79      -1.97  15:32:05.389
      2.00        5.00     95.45      51.41      20.27       1.14  15:32:05.800
       .           .         .          .          .          .     .
```

Figure 6-21: EM61-MK2 Data Stream

6.4.4.3.1. Small handheld units manufactured for recreational use are not acceptable for DGM surveys where reacquisition of anomalies is required. These units typically cost $150 to $400 and, while helpful for finding general locations, are not capable of the level of precision necessary for most DGM surveying. However, they may provide the needed accuracy for performing initial characterization work. When Selective Availability (SA) is not in use by the DoD, these GPS units can achieve accuracies of approximately 10 m. With SA activated, accuracy drops to approximately 100 m. Wide Area Augmentation System (WAAS) is a system of satellites and ground stations originally developed for aviation, which provides GPS signal corrections. WAAS-enabled handheld GPS receivers are reported to have accuracy of 3–5 m.

6.4.4.3.2. The use of DGPS allows for the correction of errors in positioning from SA and other sources, which include clock errors, atmospheric effects, and signal reflections. Sub-meter accuracy is possible using DGPS, given favorable conditions. Four types of DGPS are in use: 1) utilizing GPS base stations that transmit corrections via radio, commonly known as RTK; 2) using U.S. Coast Guard or DOT beacons transmitting corrections; 3) using a satellite-based service, such as the OmniSTAR system; and 4) Web-based differential corrections.

Post-collection processing of GPS data also is possible using data collected by a nearby base station whose data are made available to the public.

- DGPS makes use of the Carrier Phase, which allows accuracies within 1–20 cm. Correction of bias factors may be accomplished in real time, using a RTK GPS system, or through post processing (PP). Both RTK and PP systems utilize a base station, set up on a known point, which then transmits corrections to a roving GPS unit via radio (RTK), or records base station data that are used to apply differential corrections to the recorded roving GPS data (PP). DGPS is the most accurate and common form of GPS surveying performed for UXO detection.

- The U.S. Coast Guard Navigation Center operates the most widely used real-time DGPS service, utilizing two control centers and a network of broadcast stations, or "beacons." Real-time differential correction requires a GPS receiver that is tuned to the frequency of the broadcast real-time correction message. When a real-time correction message is present, the receiver applies the differential correction to GPS data concurrently with the collection of field data. An effort is underway to expand DGPS coverage through a seven-agency partnership for the Nationwide Differential GPS (NDGPS) program. The data can be accessed for free, and an accuracy of 1–10 m normally is possible using the transmitted corrections. Visit the U.S. Coast Guard Web site (http://www.navcen.uscg.gov/) to view current coverage for the NDGPS system.

- Subscription-based correction methods, such as the OmniSTAR system, use a network of reference stations to measure atmospheric interference inherent in the GPS system. Reference data are transmitted to global network control centers where they are checked for integrity and reliability. The data are then up-linked to geostationary satellites that distribute the data over their respective footprints. Using satellite rebroadcast overcomes the range limitations of ground-based transmissions. Additionally, wide-area solutions, such as those provided by OmniSTAR, correct for errors associated with a single reference station solution. The result is consistently high quality differential corrections available anywhere within the continental United States plus much of Canada and Mexico. With the OmniSTAR system, two levels of service are available: OmniSTAR VBS and OmniSTAR HP. The VBS service provides sub-meter accuracy, while the HP offers improved accuracy but its capabilities have not been evaluated for the MMRP.

6.4.4.3.3. The number and location of satellites visible to the antenna and the presence of obstructions influence the level of accuracy for a GPS reading. Depending on the project-specific needs, different levels of GPS data quality may be acceptable. Improvements to GPS performance in obstructed view areas continue to improve, and the PDT should evaluate current systems to determine if handheld GPS units may meet project objectives. Handheld GPS units may only be able to consistently achieve a 2 m level of accuracy in wooded areas; however, that may be sufficient to show that a transect was collected along a straight line. Additional factors that affect GPS data quality are discussed below:

- A factor called DOP (dilution of precision) is a measure of the level of precision that can be expected for a particular arrangement of satellites. The DOP is computed from a number of factors, including HDOP (horizontal), VDOP (vertical), and TDOP (time). Together, these factors are used to compute the PDOP (position dilution of precision). Lower DOP values indicate better accuracies are being achieved by the DGPS system. Although PDOP is commonly used, HDOP and TDOP may be more applicable to DGM work, in which the x, y coordinates are used to map anomalies. GPS accuracy in the vertical dimension is less than in the horizontal. Most GPS receivers can be programmed to output the calculated DOP values (HDOP, PDOP, etc.). For DGM surveys, DOP values should be below 6 when using code-only systems, and the DOP values should be below 12 when computing code and phase solution. These values are based on information provided by several DGPS vendors; alternative DOP maxima may be acceptable based upon the system's published technical specifications.

- Although PDOP (or HDOP) gives some indication of data quality, an important indicator of data quality is the number of satellites used for determining position and the SNR of each that is being detected by the GPS receiver. It is possible to have a low PDOP and still have significant errors in positioning, especially with few satellites and/or low SNRs from one or more satellites. A minimum of four satellites is needed to determine a three-dimensional position; however, accuracy increases with additional satellites. For DGM surveys, a minimum of four satellites should be used at all times for GPS data collection.

6.4.4.3.4. If geophysical data is recorded in a separate device from the GPS data, all measurements in each data file must have an associated time stamp, which is used later to merge the position readings with the geophysical data. This introduces a potential source of error that can be difficult to detect and correct; therefore, data collection in this manner is not recommended. Rather, all data from geophysical and navigation instruments should be streamed into a single recording device (typically a field computer), which generates time stamps for all data streams using the same system clock. When navigation and geophysical data are collected independently, it is crucial that the times be synchronized to permit accurate location of the data. GPS satellites use atomic clocks capable of extremely accurate time keeping. Most code only and code and phase systems use the satellite clock information to continuously correct any drift in the time basis of the land-based receivers. Geophysical instruments use less sophisticated clocks, which may drift in relation to the GPS clocks. Prior to collecting data, the times between all instruments must be synchronized to within 0.25 seconds for surveys performed at normal walking speeds. Tighter synchronization will be required for surveys performed at greater speeds. When finishing a grid, transect, etc., check the synchronization of the data recorders again and record any difference noted. If the difference has increased by more than 0.25 seconds (for a total difference of more than 0.5 seconds), the time differences will require correcting. A linear clock drift usually can be assumed.

6.4.4.4. A Robotic Total Station (RTS; example is the Leica 1200) operates under a different concept than the other positioning systems. The RTS essentially is an automated laser survey station that derives its position from traditional survey methodology by determining the station coordinate position and orientation based upon reference to two existing known points establishing a baseline. The RTS tracks a prism attached to the geophysical sensor and computes the location. See Figure 6-22. The robotic portion maintains track on the moving prism and records relative position and elevation in reference to the survey baseline. Dynamic positions may be recorded at several times a second.

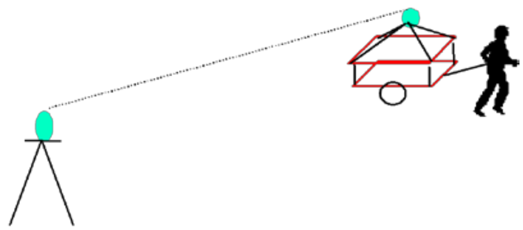


Figure 6-22: Example of RTS Single-Point Position Tracking

6.4.4.4.1. The technology must have constant line-of-sight from the single point RTS station to the roving prism. Position gaps must be interpolated with loss of line-of-sight. With the use of the appropriate firmware and operation procedures, the RTS can maintain lock in moderate wooded areas by predicting the location of the sensor and then reacquiring it following the obstructions. The technology can provide sub-centimeter accuracy for static positioning in open areas; however, interpolations for areas with loss of line-of-sight, such as obstructions caused by tree trunks and branches, dilute this precision.

6.4.4.4.2. For visibility, the prism is generally on an extended pole above the geophysical sensor. Error can be introduced by sloped terrain where the sensor lean provides a variable offset in relation to the actual sensor location. A position accuracy of 0.07–0.27 m has been demonstrated consistently in field trials.

6.4.4.5. Laser fan systems (example is the ArcSecond UXO Constellation) use the precision of laser measurements in a different way than the RTS. Rather than taking a range and angle measurement to the rover from the RTS instrument as referenced from an established baseline, the laser transmitter system takes angular measurements in reference to multiple laser transmitters or beacons. A scale factor is applied during setup by the system hardware, by reference to a known distance or by known points to establish distances and known points, which are referenced to establish the coordinate reference. These angles are solved to the rover's geometric location and scales applied for coordinate positional output. Three-dimensional position and, in some configurations, attitude and orientation are determined at up to 40 Hz. Generally, four transmitters are set up around the perimeter of the work area. See Figure 6-23. Since this system is laser based, it requires line-of-sight for the rover, but it is more accurate than the RTS in open and obstructed areas because of the high positional sampling rate and the redundancy of measurements from multiple transmitter locations. Like the RTS, three-dimensional positions must be interpolated for times when the rover does not have visibility by two transmitters. Unlike the RTS, the rover is not affected by instrument lean. The system projects the position to the desired spatial instrument reference point. Some configurations also capture attitude and orientation to permit advanced geophysical sensor modeling, which provides local high three-dimensional accuracy for anomaly interrogation. A disadvantage is the additional hardware for the multiple transmitters and a maximum range with the external transmitter strobes of 100 m. A position accuracy of 0.01–0.18 m has been demonstrated consistently in field trials (average 0.01 m interrogations, 0.04 m area navigation, and 0.11 m as picked from the geophysics).

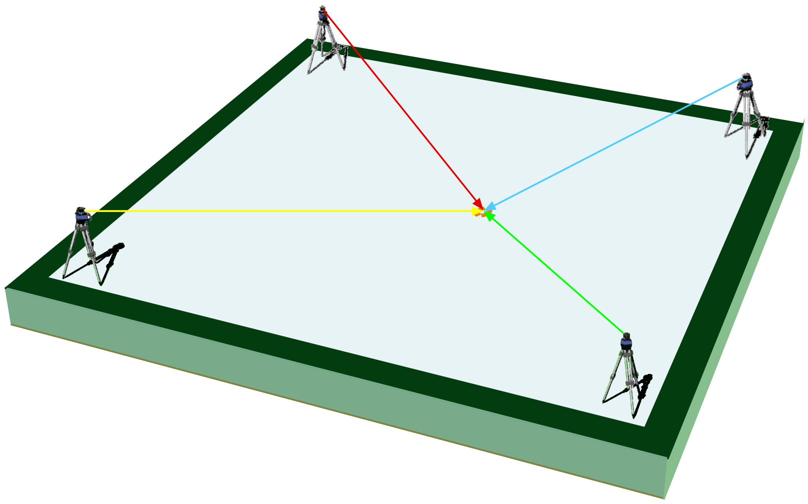


Figure 6-23:  Example of a Typical Laser Transmitter Layout

6.4.4.6.   A radio frequency (RF) system (example is the ENSCO Ranger) exploits a unique direct sequence spread spectrum measuring system to provide precision geolocation and simultaneous data communications.  Multiple base-station radios are used to measure their distance to one or more mobile radios.  These multiple distance measurements then can be used to compute the coordinates of the mobile radios.  Repeated, sequential distance measurements and coordinate computation enables tracking the mobile radio’s path.  This navigation system is directly integrated with a data logger and geophysical instrumentation.  See Figure 6-24.

6.4.4.6.1.   The RF system communications architecture is based on direct sequence spread spectrum (DSSS) in the 2.4-gigahertz Industrial, Scientific, and Medical band.  This allows the system to operate as unlicensed transmitters under Federal Communications Commission rules with a 1-watt transmit power.  Core circuitry takes advantage of widely available and inexpensive components commonly used in 802.11b wireless network products.  The key element of the system is the ability to accurately measure distance.  Methods for using a DSSS radio for semiprecise time-of-flight measurement are well understood for coarse measurement.  This system differs in that a fine measurement is made to estimate more precisely the time-of-arrival (and, hence, the distance traveled) of a signal.  It is this fine measurement that provides the sub-meter accuracy.

6.4.4.6.2.   An improvement to this system is having the radio navigation system augmented with an inertial navigation system (INS).  The INS systems use the Ranger position as a starting point and the INS to acquire a high accuracy relative position for three-dimensional instrument tracking.  A position accuracy of 0.17–0.57 m, similar to dynamic DGPS, was demonstrated for Ranger.  The INS enhancement for the interrogation areas has demonstrated a relative position accuracy of 0.03–0.05 m.

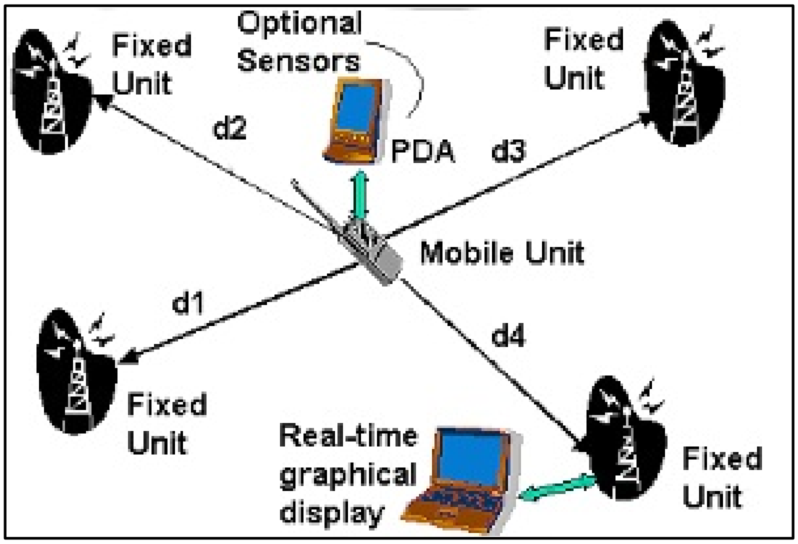



Figure 6-24: Example of an RF Positioning System

6.4.4.7. An acoustic navigation system (example is the Ultrasonic Ranging and Data System) utilizes ultrasonic techniques to determine the location of a geophysical instrument each second. It consists of three basic elements: a data pack, up to 15 stationary receivers (SRs), and a master receiver. The data pack is mounted on the geophysical sensor backpack with the ultrasonic transducer mounted approximately 1 m above the sensor. The data pack fires the transducer; by monitoring the time-of-flight, the location of the geophysical sensor can be determined. The SRs are placed throughout the survey area with about nine required per acre. A minimum of two is required to be on known points. The system software automatically determines the locations of the SRs by utilizing the time-of-flight information among all SRs. Finally, the master receiver and laptop computer act as the master timer between the components, as the data processor, and as the data collector. The computer computes the sensor position location and displays the survey data. Position accuracy of 0.15 m is expected with proper SRs distributed at up to a 150-foot spacing. Figure 6-25 shows an example of an acoustic positioning system.

6.4.4.8. Some geophysical systems incorporate additional equipment to improve positioning accuracies. These include digital tilt meters to record roll and pitch of sensor platforms and digital compasses or gyrocompasses to record platform bearing.

6.5. Geophysical System Deployment Platforms. Geophysical instruments can be deployed using various platforms in order to collect data in the most efficient manner over a particular project property.

6.5.1. Man-Portable Systems. Many geophysical instruments can be deployed using individuals to carry or pull the equipment across the survey area. See Figure 6-26.

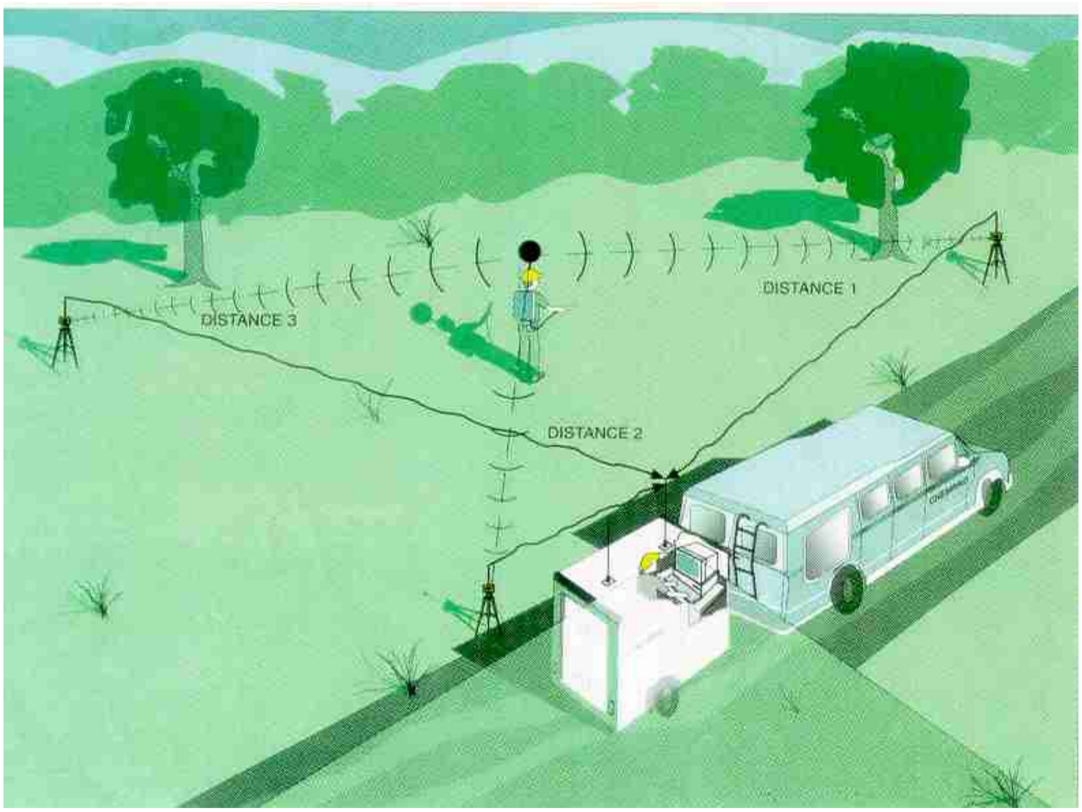



Figure 6-25: Example of an Acoustic Positioning System

Figure 6-26: Example of a Man-Portable Geophysical System

6.5.2. Multiple Instrument Arrays. In cases where a particular geophysical instrument provides good detection results and the terrain permitting, several sensors can be joined in an array that is pulled behind a vehicle to achieve greater data density and greater production rates than possible with a single sensor system. However, due to access and mobility limitations, such arrays generally are limited to large, open areas with relatively flat terrain. See Figure 6-27.

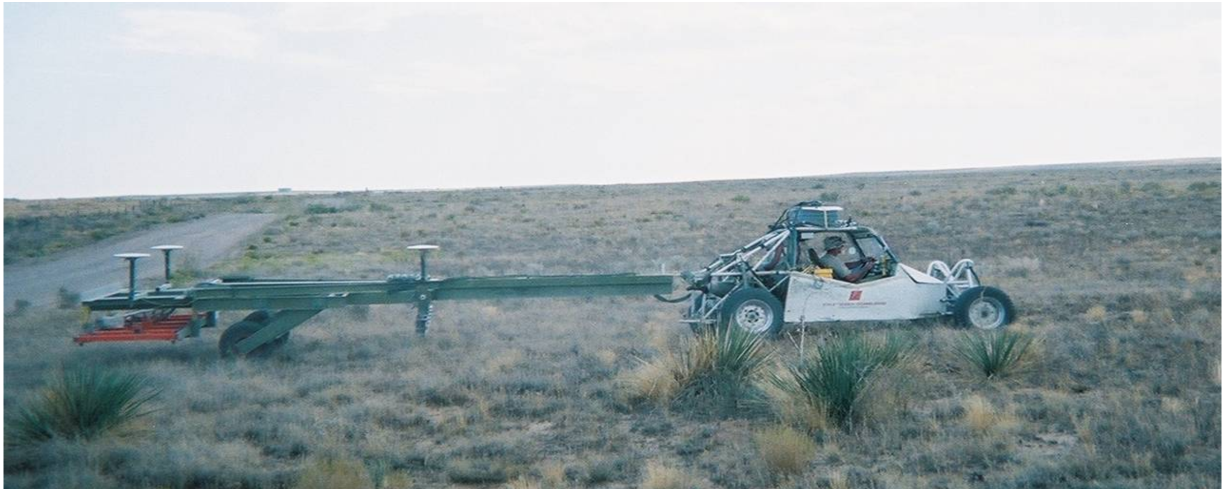


Figure 6-27: Example of a Multiple Instrument Array

6.5.3. Airborne Systems. Recent developments in sensor technology, computers, and navigation techniques have led to the effective use of airborne techniques for geophysical surveys at MRAs. Successful airborne techniques have included magnetic, electromagnetic, and LIDAR surveys. Potential airborne techniques include infrared, hyperspectral imaging, and SAR but require further validation testing using both helicopter and fixed-wing platforms. Airborne surveys have the potential to achieve greater data density and production rates than possible with ground-based systems. However, due to access and site-specific requirements, airborne surveys generally are limited to large open areas and relatively large anomalies because the increased distance from the targets to the sensor reduces the ability to detect smaller objects. At project properties where large areas exist that allow the platform to fly close to the ground (i.e., grasslands or agricultural areas), airborne systems can provide a method for footprint analysis to identify the high anomaly density areas or the location of large items. See Figure 6-28.

Figure 6-28: Example of an Airborne Geophysical System

6.5.4. Underwater Systems. Recent developments in sensor technology, computers, and navigation techniques also have led to the effective use of geophysical surveying for UXO in shallow marine environments. The surveys have included magnetic, EM, and SSS methods. See Figure 6-29.

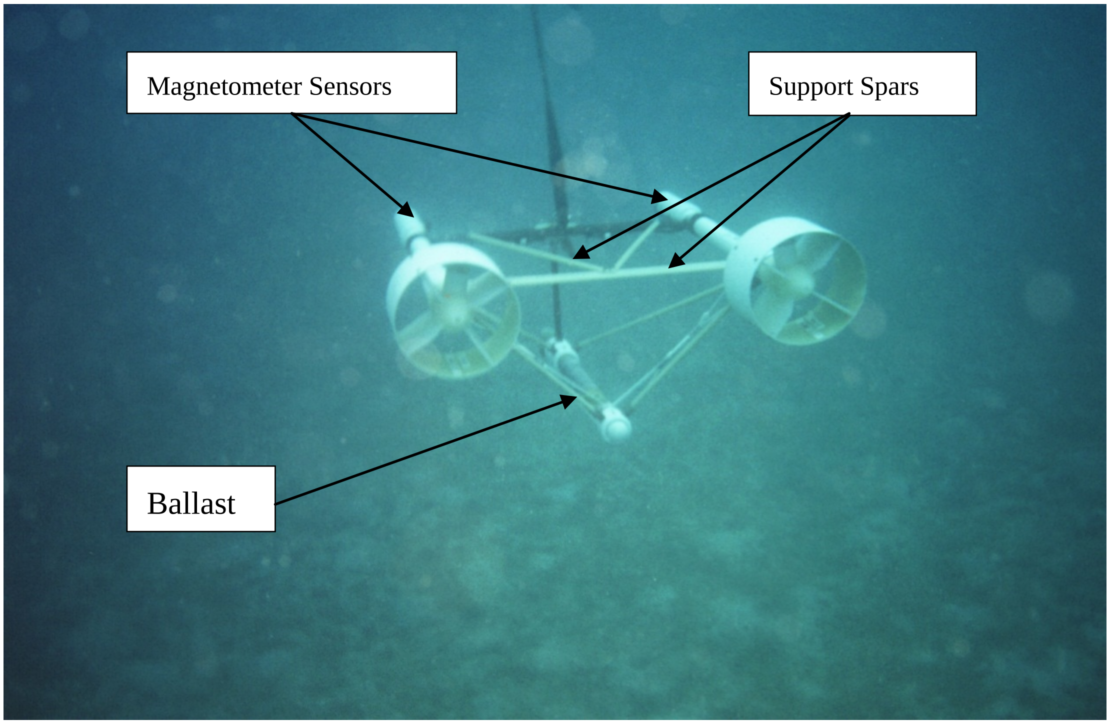



Figure 6-29: Example of an Underwater Geophysical System

## 6.6. Geophysical Data Analysis Work Flow.

6.6.1. Overview. Digital geophysical systems produce data that offer several advantages that geophysicists can use to determine what targets identified during a MR are most likely to be TOIs. Digital geophysical systems offer the ability to evaluate anomaly selection criteria and to analyze the characteristics of detected anomalies to decide whether or not they should be placed on dig lists. As discussed in Section 6.3.5 of this manual, advanced EMI sensors may be used to classify targets as either TOI or non-TOI. Based on how an anomaly is classified, a decision can be made as to whether the PDT should proceed and excavate that anomaly.

6.6.1.1. “Anomaly classification” is used in reference to determining whether anomaly characteristics indicate that a target is or is not a TOI. There is a range of meanings when using the term anomaly classification. Typically, it has been applied to the process of performing inversion of geophysical data to obtain dipole model polarizabilities; however, anomaly classification and inversion are not synonymous, and anomaly classification doesn’t always include the inversion process. Sometimes, the term may be applicable when anomalies are selected for investigation using peak anomaly response and other anomaly selection parameters (e.g., anomaly size, SNR). The inversion process extracts the dipole model polarizabilities, or betas, which then can be used to calculate feature parameters (e.g., size, decay, shape parameters) that enable the classification of anomalies as either TOI or non-TOI.

6.6.1.2. Anomaly classification methods may lead to significant cost savings during remedial and removal actions; however, classification methods may be less successful for TOI in a certain physical state (e.g., low-order rounds, asymmetrical rounds) or for some scenarios with low SNR. In addition, anomaly classification using production-level DGM sensors in survey mode is significantly less successful than when using data collected with advanced EMI sensors in a cued, static mode with the system situated over the buried metallic object (i.e., the sensor doesn't move until all data have been collected over the target). Inversion and modeling of advanced EMI data produces more accurate parameter estimates than for production-level DGM data; however, the success of any anomaly classification method is dependent on the data analyst's ability to use a computer model to accurately estimate anomaly parameters. The more accurate parameter estimates can lead to a much greater reduction in the number of non-TOIs that requires excavation to ensure that all TOIs have been removed from the site. Inversion-based classification using production-level DGM data may be possible given very specific site conditions, which include a limited number of TOI types at the MRS, the types of TOI at the MRS are large, and the non-TOIs at the site are much smaller than the TOI types. Classification attempts using data collected from production-level DGM surveys are more limited in their ability to accurately reproduce anomaly parameters than advanced EMI sensors due to the following limitations:

a. Survey data are recorded over a relatively small time window within the decay curve.

b. Sensor positioning uncertainty degrades target parameter estimates.

c. Across-track and down-line spacing may not provide adequate sampling of the response of the subsurface metallic item.

d. Overlapping signals from multiple items cannot be distinguished with current processing (but they can with the advanced sensors).

e. Strong SNR approaching 100 is required for classification (Keiswetter, 2010).

f. The EM61-MK2 has a limited number of time gates.

g. The recorded signal shape is distorted by analog smoothing (i.e., averaging of the response within a time window).

h. Towed arrays have limited target illumination with transmitters operated simultaneously.

i. Averaging functions and stacking functions in the EM61 degrade true decay characteristics.

6.6.1.3. Figure 6-30 shows the classification process, or geophysical data analysis work flow, that geophysicists should use to determine which anomalies are TOIs (and, therefore, should be put on the dig list) and those anomalies that are not TOIs (and should not be put on the dig list). The anomaly classification process consists of a series of steps plus QC processes for each of the steps (see Chapter 11 for discussion of anomaly classification QC). The steps within the anomaly classification process and the section in this chapter in which each step is discussed are listed below.

a. Conduct production-level DGM surveys.

b. Select anomalies from the DGM data (see Section 6.6.2).

c. Invert DGM targets for their location (optional; see Section 6.6.3).

d. Acquire cued data using an advanced EMI sensor (optional; see Section 6.6.4).

e. Extract anomaly parameters (see Section 6.6.5).

f. Collect training data (optional, see Section 6.6.6).

g. Set classifier rules and apply classifier (see Section 6.6.7).

h. Populate dig lists (see Section 6.6.8).

i. Conduct anomaly resolution (see Section 6.6.9).

j. Evaluate dig results and classifier performance through a feedback process (see Section 6.6.10).

6.6.1.4. The primary goal of anomaly classification is to identify geophysical anomalies that cannot be caused by UXO or DMM (i.e., non-TOIs) so that the non-TOIs can be removed from the dig list and left in the ground. The process and decision rules that the qualified geophysicist uses to determine whether anomalies are TOIs or non-TOIs must be considered on a site-by-site basis, be based on knowledge of the anticipated UXO at the site, be documented, make logical sense, and be based on an assessment of the data from which the model parameters were extracted. When the geophysicist is uncertain whether feature parameters indicate an anomaly is a TOI or not a TOI, it is almost always better to include the anomaly on the dig list. This is especially true for removal actions that may be the final stage of investigation at the MRS. For earlier stages (such as the RI phase), it may be less critical to recover all selected anomalies; however, unsampled populations of UXO during the RI may lead to incorrect assumptions about the nature of UXO within the MRS during later MMRP phases. Throughout the intrusive process, a feedback loop should be employed to evaluate dig results to assess the effectiveness of the classifier. If TOIs are found at anomalies that were not classified as TOIs, the classification method should be modified.

6.6.2. Selecting Anomalies. A geophysical anomaly is defined as geophysical measurement(s) that are distinguishable from nearby background measurements. Quantifiable anomaly characteristics are limited to digital geophysical mapping systems and some analog systems that provide a digital readout of the instrument's measurements. Quantifiable characteristics are identified below. All other systems offer only the ability to use qualitative characteristics to detect and select anomalies. We use the terms "anomaly detection" and "anomaly selection" independently, though in some systems, particularly in analog systems, these two actions occur simultaneously. Anomaly detection is used in reference to how above-background measurements (anomalies) are identified. The anomaly selection process is how above-background measurements are selected for further evaluation through the anomaly classification process. Section 6.6.2.2 presents discussion of detecting and selecting anomalies for analog geophysical systems, while the remainder of this section discusses the individual components of the DGM data anomaly selection process.

6.6.2.1. Pre-processing of Geophysical Data. Many software packages can be used to evaluate geophysical data. Often the geophysical equipment manufacturers provide specialized software for specific systems. This software is used primarily to transfer the data from the instrument to the computer and perform corrections to the data. Corrections such as navigation adjustments and rotation and translation of coordinate systems are necessary before analyzing the data. The corrected data then are transferred into a software package designed to facilitate contouring, mapping, and selection of anomalous data potentially representing UXO.

6.6.2.1.1. Field editing of the data includes removal of data spikes, correcting for fiducial marks, and exporting ASCII data files.

6.6.2.1.2. Initial processing (sometimes referred to as "pre-processing") of the geophysical data includes incorporation of navigation and positional information, instrument drift and leveling, heading error corrections, and latency corrections.

6.6.2.1.3. All processing needs to be well documented so that results can be checked and procedures verified.

6.6.2.2. Detecting and Selecting Anomalies with Analog Systems. Analog systems used in audio mode or by monitoring meter deflections only offer the ability to discern relative size and relative signal strength. An experienced operator sometimes can use these characteristics to estimate source depth and source size, but such estimates are subjective in nature. Often the option for selecting or rejecting anomalies detected with these devices is limited to rejecting only those anomalies with very small spatial extent (small size) and high signal strength characteristics. Such anomalies are expected to be associated with small near-surface metallic sources because the strength is high (if the small piece of metal were deep, the strength would be much less) and the spatial extent is small (if the source were a large piece of metal, the spatial extent would be large). If small UXO is a TOI, this approach would not be valid. Due to their inherent limitations, analog systems do not offer any additional options for differentiating TOIs from non-TOIs based on anomaly characteristics. All claims made by contractors or field personnel regarding their ability to classify TOIs from non-TOIs should be proven for each system (i.e., instrument and operator) via demonstration and continually verified in the field throughout project execution via blind seeding and post-dig verification.

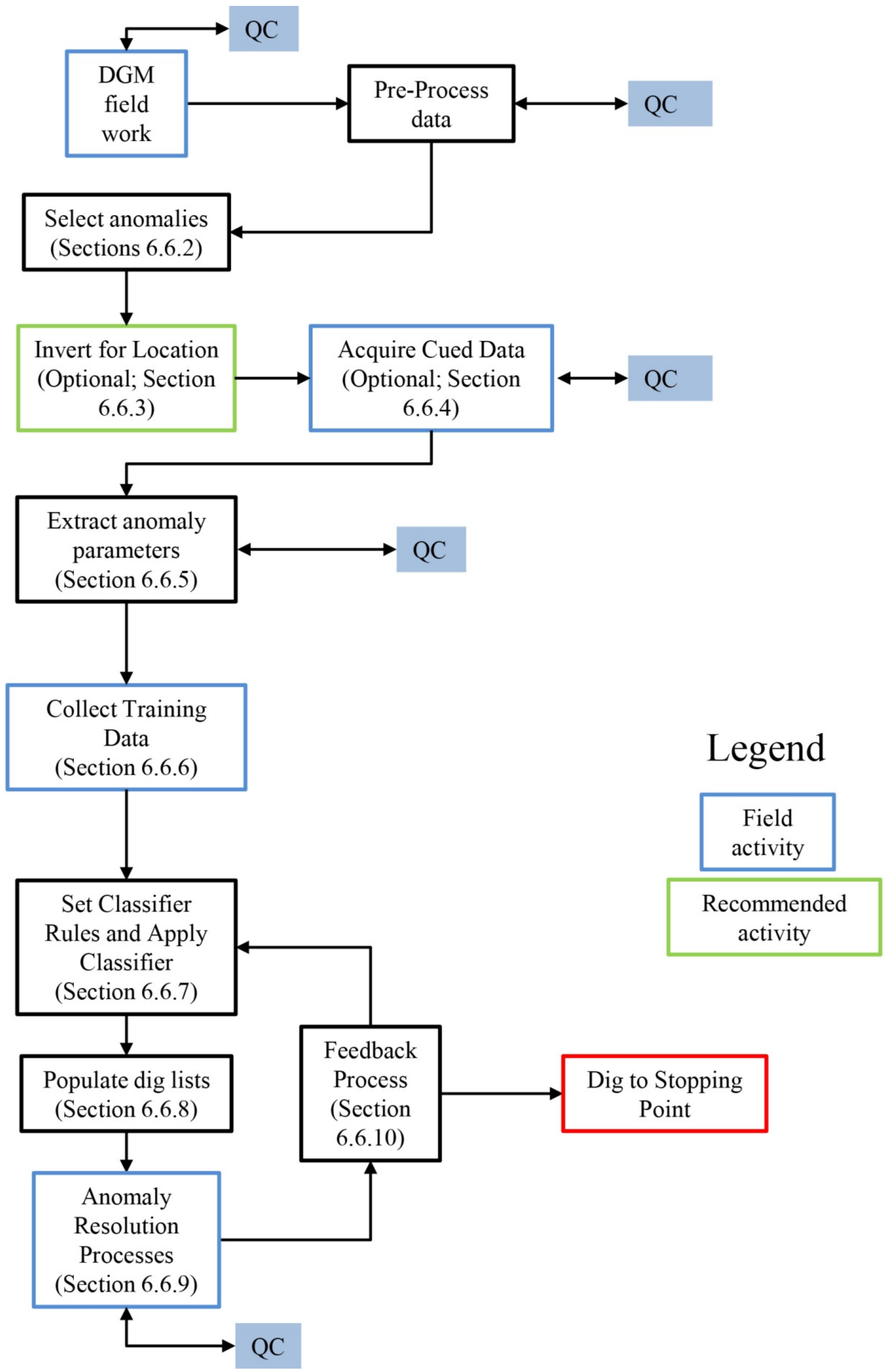



Figure 6-30: DGM Data Analysis Workflow

6.6.2.3. Detecting Anomalies from DGM Data. DGM systems offer the ability to quantify numerous anomaly characteristics. One or more of these characteristics are used to distinguish whether the characteristic values for one measurement or a group of two or more contiguous measurements are distinguishable from background measurements. This process often is automated using software tools. Table 6-3 lists common anomaly characteristics that can be quantified using DGM systems, the reliability of the estimate of the feature, and the relative ease of feature extraction during inversion (note that this relative ease considers the amount of time to extract the parameter but does not factor in the amount of time required to refine polygons used to select data for inversion). These anomaly characteristics are used to provide justifications and explanations for not excavating all anomalies that may meet one or more non-critical characteristic criteria. Basically, when anomaly selection criteria are defined, certain assumptions are attached to those criteria because it is not technically feasible to unambiguously define each anomaly characteristic for each TOI type and scenario (item condition, item depth and orientation, local clutter, geology variations, etc.) on an individual project site. The solution is to define selection criteria that are conservative enough to reliably select geophysical anomalies for analysis in the classification process. In addition, 5% to 20% of non-TOIs (i.e., anomalies that would not otherwise be placed onto dig lists) should be added to the dig list as a measure of continuously checking the assumptions used in developing the anomaly selection criteria.

Table 6-3: Production-Level DGM Data Parameters

| Feature Parameter | Reliability of DGM Anomaly Characteristics / Extracted Parameters | Relative Ease of Obtaining from DGM Data |
|---|---|---|
| Anomaly peak response for all channels of data recorded | High | Medium |
| Spatial extent (area) of above-background measurements | High | Easy |
| Estimated target depth | Low | Easy |
| Estimated SNR based on all above-background measurements (also referred to as the anomaly power SNR) | High | Medium |
| Estimated magnetic moment (for magnetometer systems) | High | Easy |
| Estimated time-constant and related decay-curve characteristics (for TDEMI systems) | High | Easy |
| Estimated polarizabilities | Low | Hard |
| Estimated conductivity and susceptibility (FDEMI) | High | Easy |
| Estimated shape | Low | Hard |
| Estimated size | Medium | Hard |
| Estimated location of item's center | Low | Hard |
| Estimated weight | Low | Hard |

6.6.2.4. Selecting Anomalies using Response Curves. For a well-characterized sensor, such as the EM61-MK2 or magnetometers, the geophysicist should use sensor response curves to determine the peak anomaly response threshold to use in anomaly selection. NRL has calculated the theoretical sensor response curves for standard munitions items and industry standard objects (ISOs) for the EM61-MK2; they are available in NRL Report NRL/MR/6110--08-9155: EM61-MK2 Response of Standard Munitions Items and NRL Report NRL/MR/6110--09-9183: EM61-

MK2 Response of Three Munitions Surrogates, respectively. The above NRL Report on ISOs, as well as the ESTCP report on the Geophysical Systems Verification (GSV) process (ESTCP, 2009), shows that ISO response is approximately equal to the EMI response for similar shaped/length munitions. The same is true for munitions for which curves do not yet exist but have similar shape/length as those that have curves. The above reports, as well as a response calculator to generate response curves for additional munitions types, can be downloaded from http://www.serdp-estcp.org/Tools-and-Training/Munitions-Response/Geophysical-System-Verification/GSV-Response-Calculator. NRL also has calculated theoretical response curves for standard munitions items for magnetometers; they are available in NRL Report NRL/M/6110—12-9385 and can be downloaded from http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA557775. This report includes tabulated magnetometer response curves and scaling factors for changes in orientation and strength of the Earth's magnetic field due to location, as well as discussion of the difficulties encountered due to remanent magnetization.

6.6.2.4.1. The theoretical response curves can be used to determine an anomaly selection threshold using either of the following two methods:

6.6.2.4.1.1. Anomaly Selection Based on Removal Depth. If the PDT needs to remove all munitions to a given depth, they can use the sensor response curves to determine the theoretical sensor response in the least favorable orientation for each anticipated munitions type at the site. The anomaly selection threshold should be adjusted from the theoretical response to account for errors encountered during DGM data collection (e.g., sensor bounce) and to add a conservative factor to account for the potential of other response factors associated with how systems are deployed. This anomaly selection method can be performed prior to mobilizing to the field and without the aid of Instrument Verification Strip (IVS) data evaluation.

6.6.2.4.1.2. Anomaly Selection Based on TOI Type and Background Noise. The theoretical sensor response curves also may be used to determine the anomaly selection threshold when the PDT wants to investigate all anomalies but doesn't know the maximum depth to which the TOI will be removed. In this scenario, the anomaly selection threshold should be based on some multiple of the RMS background noise measured at the IVS (typically five to seven times the RMS noise) for the munitions with the smallest response in the least favorable orientation. As when basing anomaly selection on the removal depth, the anomaly selection threshold should be adjusted downward to account for inherent signal level variations encountered during dynamic DGM data collection. Figure 6-31 shows an example of determining an anomaly selection threshold based on the RMS noise. In this example, the RMS noise is approximately 0.75 millivolts (mV); the geophysicist has chosen to base the anomaly selection threshold on a value of five times the RMS noise (or 3.75 mV). Without factoring for potential noise and error sources, the theoretical maximum detection depth for the most conservative munition in the least favorable orientation in this example is approximately 14 inches below ground surface (bgs) and approximately 26 inches bgs for the most favorable orientation.

6.6.2.4.2. If seed item response curves don't exist for a particular munition that will be used to develop the anomaly selection threshold at a site, the geophysicist should develop response curves by measuring the response of the munition at multiple depths for the most (i.e., vertical) and least (i.e., horizontal along track) favorable orientations. Once the test measurements are made, the theoretical curves can be calculated using the response calculator available at http://www.serdp.org/Tools-and-Training/Munitions-Response/Geophysical-System-Verification/GSV-Response-Calculator.

6.6.2.4.3. Many selection criteria initially are based on the theoretical response curves. While the theoretical response curves for TOIs are well documented, variations in response due to orientations and offsets of the buried items, site-specific noise, and errors due to data collection variables (e.g., sensor speed, sensor bounce) could cause the measured response in the production-level DGM survey to fall outside the theoretical response curves. In addition, known errors in accurately measuring seed depth, orientation, bounce, etc. could lead to 50%+ difference from predicted value, which may or may not give the geophysicist confidence that the instrument is operational. In order to more tightly reproduce the response curve value, data should be collected in a static mode with an ISO on a jig or some fixed and easily measured offset from the coil as an initial test. Once this has proven that the instrument itself is functioning as expected, a project specific IVS value may be determined by averaging response over several initial runs and then requiring a tighter % reproducibility to this value to show repeatability and continued functioning of the instrument. Studies show that increasing the speed of data collection increases signal noise and decreases anomaly peak responses and SNR (USAESCH, 2004). It also is known that there is a high degree of variability in responses from different TOIs of the same model when buried in the same orientation and at the same depth (USAESCH, 2011). Therefore, anomaly selection criteria may require a degree of conservatism be included in their definitions.

6.6.2.4.3.1. The theoretical response curves were developed for items centered underneath the sensor. Variations in offset and orientation of the anomaly source affect the measured response when the source is under the footprint of the sensor, and the anomaly drop-off is even greater when the anomaly source is outside the sensor footprint. Because the actual data line spacing varies from the designed line spacing (e.g., due to obstructions in the field, not walking a straight line), a worst-case scenario line spacing should be evaluated during the planning stages of a project to determine how the actual line spacing may alter the maximum detection depth for the site-specific TOI. The response calculator can be used to determine the predicted response at worst-case scenario offsets given planned line spacing.

6.6.2.4.3.2. In order to account for measurement variability during the DGM survey, the geophysicist should evaluate the different error sources that may affect the theoretical maximum detection depth capability of the DGM sensor. Error sources in the field may increase or decrease the measured DGM response relative to the theoretical sensor response curves. Errors that decrease measured responses decrease the depth to which the DGM sensor can reliably detect munitions. Failure to account for field variations in measured responses leads to inaccurate determinations of the depth to which TOIs have been removed from the site, as well as inaccurate estimates of the residual hazards remaining on the MRS after the investigation has been completed. Error sources may be evaluated at the IVS or by estimating the approximate variations that may be encountered during field activities.

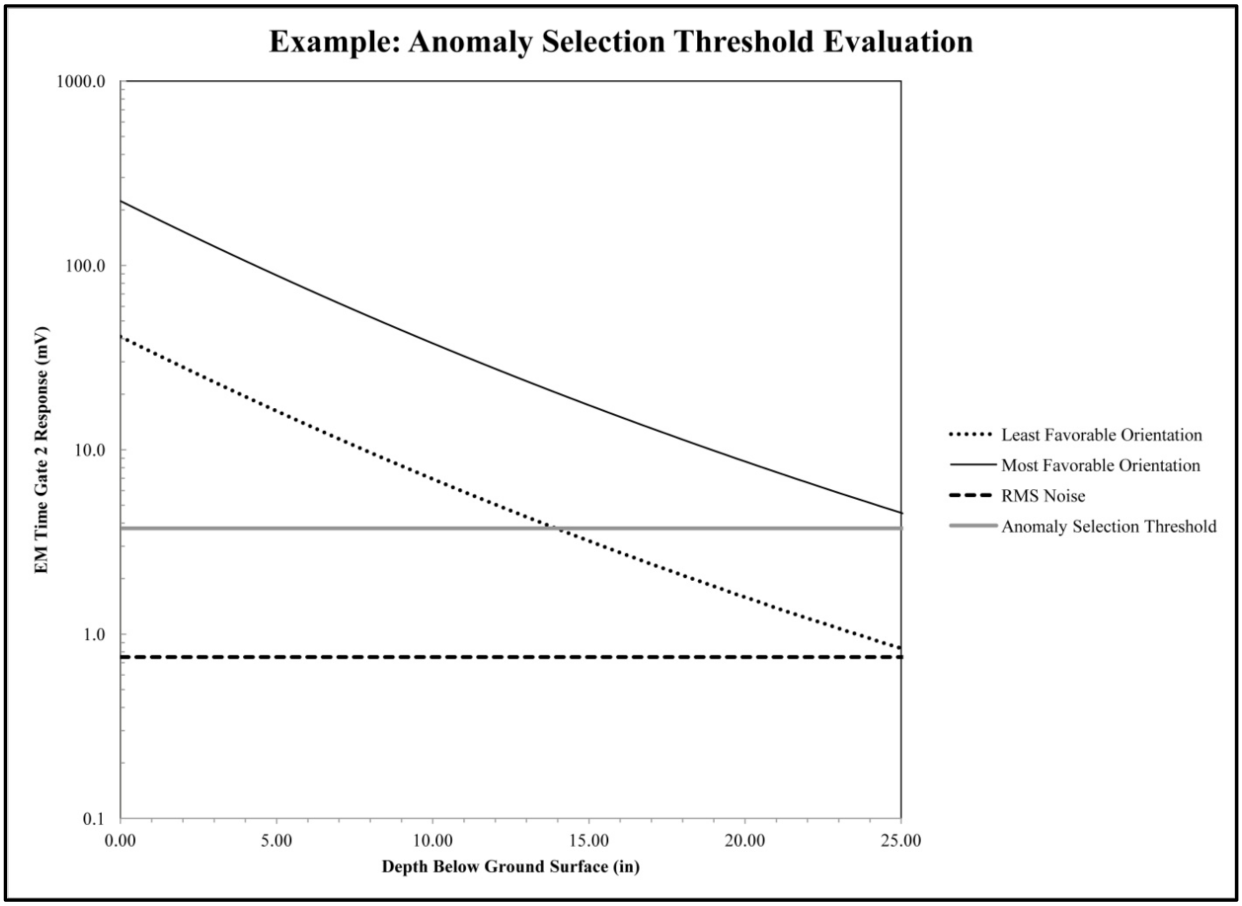



Figure 6-31: Anomaly Selection Threshold Selection Example

6.6.2.4.3.3. The estimation of error sources, or measurement variability, is required to account for process-specific effects that alter the ability of the geophysical system's depth detection capabilities and must be quantified and accounted for to ensure the project's DQOs are met. In order to quantify or estimate the potential effects on the depth detection and anomaly selection criteria, error ranges for each error type need to be quantified and then summed. The potential effects associated with each error type should be quantified or estimated. Once the individual errors are determined, the geophysicist should sum the individual errors to determine the total error for the project. Figure 6-32 presents an example of estimating the error in the IVS for three types of error. These errors are not the only types of errors that the geophysicist should consider but are three of the most common types of errors. The variation in response for each error type should be determined, and then their cumulative effect on the measured response should be calculated. The geophysicist should factor the total cumulative error bars into their anomaly selection threshold evaluation.

6.6.2.4.3.4. It is critical that the manner in which anomaly characteristics are defined factor in slight variations in data quality, such as changes in instrument height, changes in survey speeds, variations in coverage densities, variations in background levels, and changes in filtering/leveling parameters that are used. The goal is to demonstrate the field data are of the same quality and were collected and processed using the same parameters as the data used to define the anomaly selection criteria. Normally, the QC plan includes tests to confirm these parameters in field datasets do not vary significantly from those of the datasets used to define the anomaly selection criteria.

6.6.2.5. TOI Detectability. TOI detectability is dependent upon numerous factors; the general rule is "the larger the TOI, the deeper it can be detected." The theoretical response curves, as discussed above, provide the basic detection abilities for a well-characterized sensor. Many factors must be considered when evaluating whether a given geophysical system or technique can detect a given TOI at a specified burial depth. Factors that are specific to TOIs that affect how deep they can be detected include their length, diameter, surface area, volume, weight, and three-dimensional orientation with respect to the geophysical sensor when the sensor is passed over them. Factors of the geophysical systems that are relevant to TOI detection depths for EMI sensors and magnetometers are presented in Tables 6-4 and 6-5, respectively.

6.6.2.6. Penetration Depth Considerations. The maximum possible depth of TOI at an MRS is an important consideration in the selection of an appropriate detection system. If munitions are buried intentionally (i.e., the munition is DMM), factors affecting burial depth may include type of soil, mechanical vs. hand excavation, and depth of water table, among others. If the munition was fired or dropped, then the depth of penetration can be estimated by considering soil type, munition type and weight, impact angle, and impact velocity. There are many cases where UXO can penetrate deeper than geophysical systems currently can detect reliably. At such locations, it is possible that undetected UXO remains deeper than it can be detected. Recent attempts to quantify the depth penetration range for specific munitions include the development of UXO-PenDepth software (ESTCP, 2010). Because UXO-PenDepth is still in development, it is not required to be used on projects; however, the calculations may enable the user to determine the approximate depth range of fired UXO at a particular range. If used, the software should be used with care since comparisons with actual sites indicate that UXO sometimes can be found at depths greater than those calculated using the software (ESTCP, 2010). The topic of ordnance penetration is still under discussion in the MMRP community. For up-to-date information on this topic, contact the EM CX.

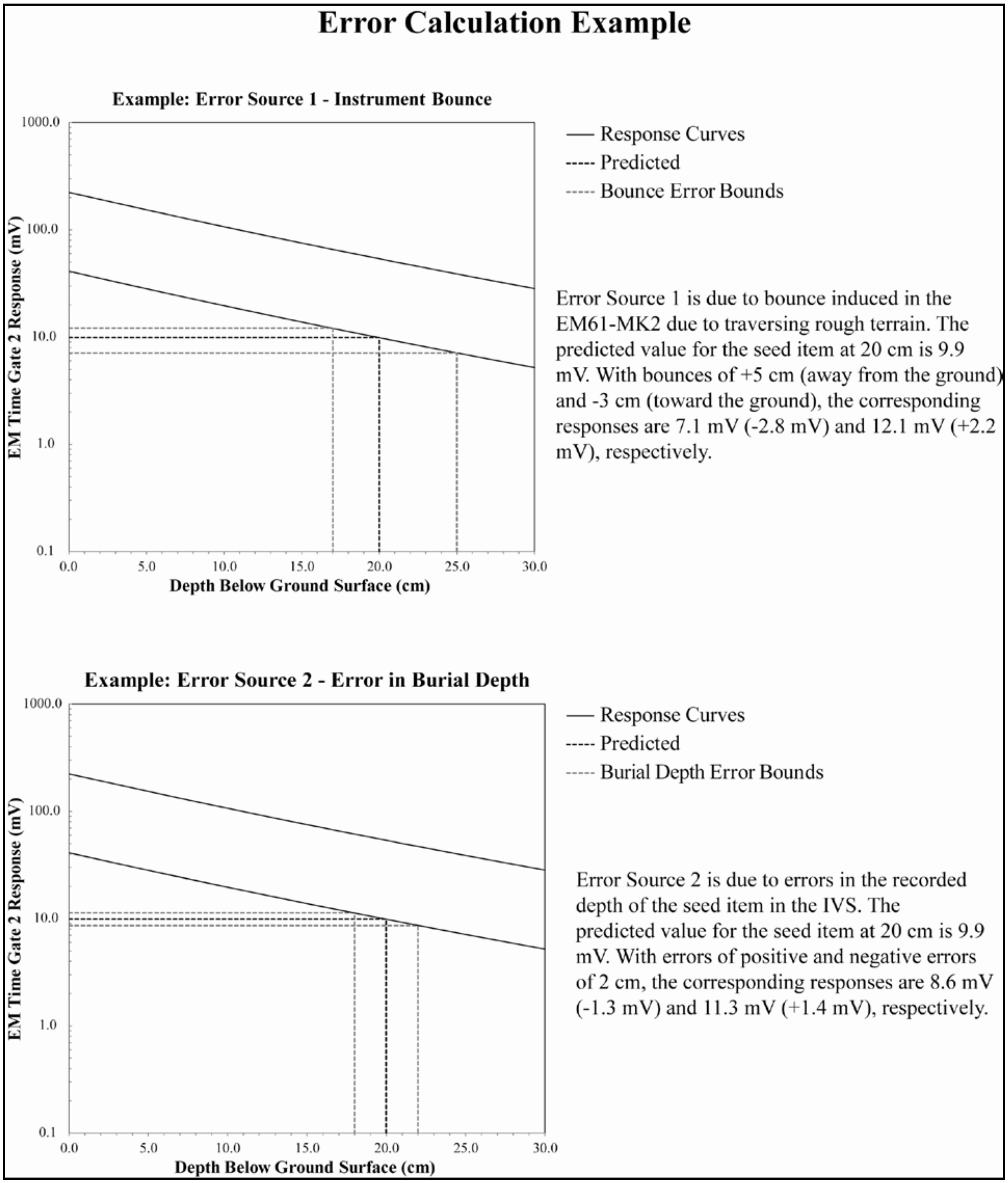
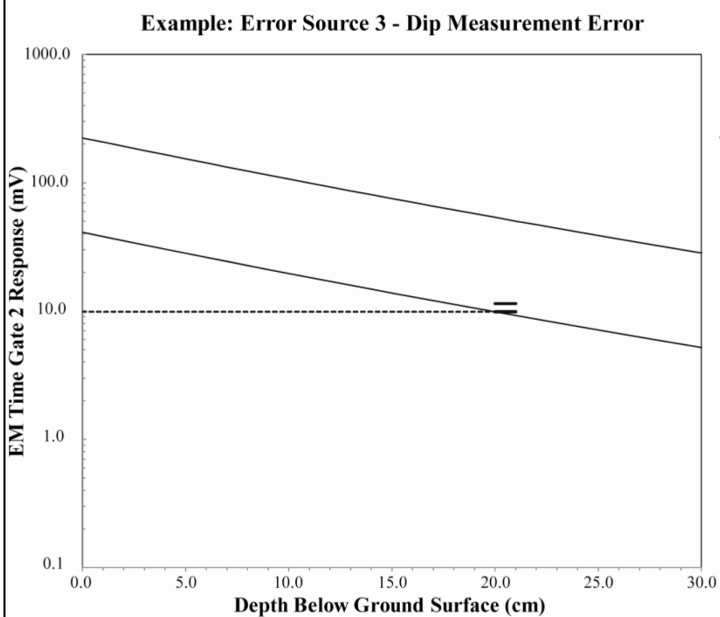


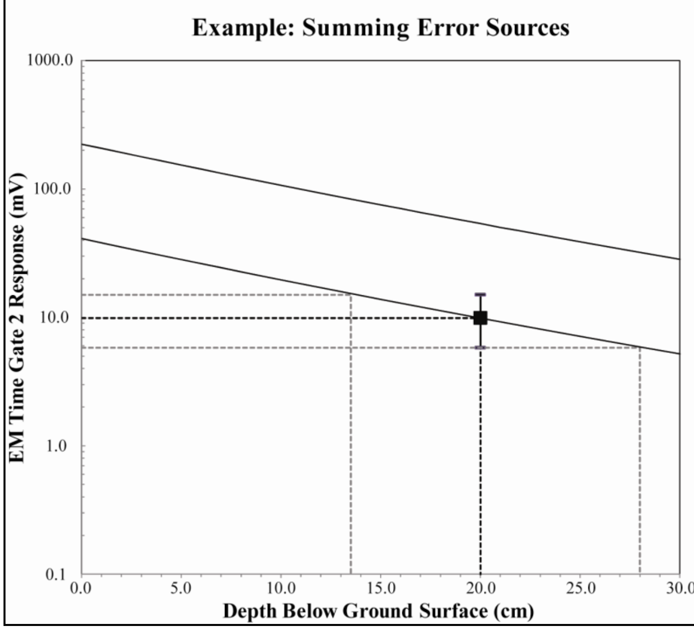

Figure 6-32:  Estimating Measurement Variability and Error

## Error Calculation Example (continued)




— Response Curves
----- Predicted
**—** Dip Angle Error

Error Source 3 is due to recording that a seed item was placed in a horizontal orientation, but was actually placed with a slight dip. The predicted value for the seed item at 20 cm is 9.9 mV. With a dip angle of +/- 5 degrees, the corresponding response is 11.4 mV (+1.5 mV). Note that there is no negative effect of identifying that the seed item is horizontal when it is not. There is a negative effect on the recorded response when vertical seed items are not actually vertical; however, the response should still fall within the response curves.




— Response Curves
----- Predicted
----- Sum of Error Bounds
Predicted Response with Sum of Errors

The final step in estimating the affects of errors is to sum both the positive and negative errors. In this example, the errors are the following:

*Positive Effects:*
- Bounce: +2.2 mV
- Burial Depth: +1.4 mV
- Dip: +1.5 mV
- ***Total: +5.1 mV (total of 15 mV)***

*Negative Effects:*
- Bounce: -2.8 mV
- Burial Depth: -1.3 mV
- Dip: none
- ***Total: -4.1 mV (total of 5.8 mV)***

Figure 6-32: Estimating Measurement Variability and Error (continued)

Table 6-4: Effect of Various Factors on TOI Detectability for EMI Sensors

| Factors that Affect TOI Detectability | Effect on EMI Sensors |
|---|---|
| Physical size of the instrument sensor | Larger EMI sensors transmit a larger current and create a larger magnetic field, thereby increasing the TOI detection depth. |
| Operating power of the transmitter coil | Increasing the operating power of the transmitter coil increases the TOI detection depth. |
| Sensitivity of the receivers | Increasing sensor sensitivity increases the EMI sensor TOI detection capabilities. |
| Measurement/sampling densities | Increased sampling densities increase the TOI detection depth ability of EMI sensor, particularly for small TOIs. |
| Speed of the survey platform | Increased survey speed decreases the SNR and the data density, which may decrease the effective TOI detection depth. |
| Distance of the coils above the ground | Sensor response falls off as $1/r^6$, where r is the distance between the transmit coil and the object. |
| Geologic/cultural/environmental conditions | Geologic and other cultural features (e.g., electric power lines) can increase the noise and decrease the TOI detection depths for EMI sensors. |

Table 6-5: Effect of Various Factors on TOI Detectability for Magnetometers

| Factors that Affect TOI Detectability | Effect on Magnetometers |
|---|---|
| Sensitivity of the magnetometer | Increased magnetometer sensitivity increases the TOI detection depth. |
| Measurement/sampling densities | Increased sampling density increases the TOI detection depth. |
| Speed of the survey platform | Increased survey speed decreases data density and may decrease the effective TOI detection depth. |
| Distance of the sensor above the ground | Sensor response falls off as $1/r^3$, where r is the distance between the magnetometer sensor and the metallic object. |
| Geologic/environmental conditions | Magnetometers are greatly influenced by rocks/soil with viscous remanent magnetization. The increased geologic noise can significantly decrease the TOI detection depth of a magnetometer. |

6.6.3. Invert for Location. As discussed above, anomalies typically are selected using automated target selection routines that place targets at the peak of an anomaly. The locations of these targets are dependent on the positioning system employed during the DGM data collection as well as the corrections applied to those locations during data processing. The geophysicist should evaluate whether performing anomaly inversion and feature extraction of the DGM data (see Section 6.6.5 for further discussion of feature extraction) may aid in further refining the interpreted target locations. This extra step should be considered for production-level DGM data to refine the target location to help minimize anomaly and target reacquisition errors that could negatively impact cued data acquisition and the resulting feature parameter estimation. If the inversion is successful, the inverted locations may be better representations of the actual location of the buried metallic object than target locations derived from traditional anomaly "peak-picking." There are multiple factors to consider in determining whether performing this extra data processing procedure on DGM data makes sense for a particular site. Successful inversion of DGM data is highly dependent on down-line data density, line spacing, the type of TOIs present at the site, and SNR. In order for this additional step to be useful to the project team, the data analyst must be able to accurately determine when the inverted results are usable, and the time required to implement this step also must be considered against potential gains. For example, the inversion process can be very time consuming and not very effective for high anomaly density areas, but these may be the areas where it could be most beneficial in reducing reacquisition problems.

6.6.4. Acquire Cued Data. After anomalies have been detected and selected for further interrogation from production-level DGM instruments or from advanced EMI sensors operating in survey mode, the geophysicist may collect cued data over the interpreted target location. Cued data are collected in static mode by placing an advanced EMI over the interpreted target location and collecting from the full EMI response. Cued data also can be collected using a grid template centered over the target location. It is critical that the advanced EMI be placed over the object to the extent practical. If later feature parameter estimation indicates that the sensor wasn't placed within some distance from the target location (e.g., within 0.4 m), the resulting model inversion may not be sufficient to properly apply the classifier, and the cued data may require being collected again.

6.6.5. Extract Anomaly Parameters. Advanced EMI systems offer the ability to perform an inversion of the cued data to classify anomalies identified during a DGM survey. The inversion extracts the dipole model polarizabilities, or betas, which then can be used to calculate feature parameters (e.g., size, decay, shape parameters) that enable the classification of anomalies as either TOI or non-TOI. There are three types of parameters that are obtained throughout the geophysical data analysis workflow: anomaly selection parameters, parameters extracted through anomaly inversion, and parameters calculated from the extracted parameters. These parameters are discussed below.

6.6.5.1. Anomaly Selection Parameters. Anomaly selection parameters are appropriate for use in identifying anomalies in DGM data and are discussed further in Section 6.6.2. Anomaly selection parameters also can be used to classify anomalies; however, their use is much less accurate than using the betas and calculated parameters discussed below.

6.6.5.2. Extracted Parameters. The dipole model polarizabilities are extracted from the advanced EMI sensor data during anomaly inversion. Polarizability is a tensor relating responses in x, y, and z directions to the primary magnetic field response in the x, y, and z directions (Pasion, 2011). After a suitable yaw, pitch, roll rotation aligns the magnetic field components with the target's three orthogonal axes, the tensor is then diagonal and the remaining elements of the tensor are the principal axis betas (e.g., $\beta_1$, $\beta_2$, $\beta_3$) that correspond to excitations in the three principal axis directions of the target.

6.6.5.3. Calculated Parameters. Once extracted from the data, the primary axis polarizabilities can be used in equations to calculate additional anomaly characteristics (or feature parameters) to use in the classification of anomalies as either TOI or non-TOI. These parameters are project-specific and require third-party verification. Review the SERDP-ESTCP Web site for the latest information on current methodologies to evaluate polarizabilities, determine size and shape parameters, and classify targets as either TOI or non-TOI. Common anomaly characteristics used in the classification process include, but are not limited to, the following:

6.6.5.3.1. Size parameters correlate the net polarizability (i.e., a measure of the sum of polarizabilities) to the size of the anomaly source (Bell, 2007).

6.6.5.3.2. Symmetry of an anomaly is a measure of the object's shape. Most, but not all, TOI is axially symmetric, and $\beta_2$ is approximately equal to $\beta_3$ for these TOI.

6.6.5.3.3. Decay attributes measure the decay of the polarizability over time and can be calculated for any time gate or principle axis polarizability. The rate of polarizability decay relates to the thickness of the metal wall.

6.6.5.3.4. Aspect ratio of an anomaly is a measure of the object's shape.

6.6.5.3.5. Fit coherence is a measure of how well a model fits the measured data, which is equal to the square of the correlation coefficient between model fit and measured data (Pasion, 2011; UX-Analyze).

6.6.5.3.6. If errors are encountered during the anomaly inversion process, a qualified geophysicist should evaluate each target that returns an error to determine whether additional processing of the data would fix the source of the error (e.g., larger windowing of the data returns a stable inversion). If additional data processing doesn't fix the source of the error, the error may require re-collection of the data, placement of the target on the dig list, or further data analysis. Through further data analysis, the qualified geophysicist may be able to determine that the anomaly data doesn't need to be re-collected or the target dug (e.g., original response was not strong enough to fit because there was no anomaly in the original DGM data or make a decision based on the data available).

6.6.6. Collect Training Data. Once feature parameters are extracted, the qualified geophysicist, or designee, should evaluate the features to determine if there are feature clusters that are indicative of TOIs. These feature clusters may be used to determine a preliminary set of classifier rules (see Section 6.6.7) upon which the target classification would be based. Prior to applying these preliminary classifier rules to the entire dataset, the geophysicist has the option to collect training data, which involves investigating a select number of anomalies to verify the anomaly classifier rules. Training data may not be needed depending on the project-specific TOI and the classification method (e.g., if applying library matching and the geophysicist is very confident that the TOIs are all known and represented in the library). If the geophysicist chooses to collect training data, the amount of training data required likely would vary on a project-specific basis. However, the geophysicist should attempt to evaluate all feature clusters that could be TOIs in sufficient detail to determine the effectiveness of the proposed classifier.

6.6.7. Set Classifier Rules and Classify Anomalies. The classification of targets requires a principled, data-driven approach to classify targets as either TOIs or non-TOIs by analyzing the feature parameters extracted from the data. Classification involves using the extracted feature parameters to identify those anomalies that cannot possibly be due to UXO (Keiswetter, 2010). The qualified geophysicist may use any of the feature parameters discussed in Section 6.6.5 as a basis for a classifier, so long as the feature can differentiate between TOIs and non-TOIs. The below sections present a brief overview of the classification process. Consult the EM CX and the SERDP-ESTCP Web sites (http://www.environmental.usace.army.mil/director.htm; http://www.serdp-estcp.org/) for further guidance on classification in general and on selecting feature parameters for a given site and determining the classifier threshold. There are two basic approaches to developing classification decisions: statistical classifiers and library matching classifiers (Bell, 2011). Both types of classifiers are based on signal matching. Library-based classifiers compare anomaly features to features of known TOIs, while statistical classifiers compare against the dataset and create their own library. Recent demonstrations indicate inexperienced personnel have difficulty identifying unexpected munitions types or isolated occurrences of an individual munitions, and almost all personnel are challenged in correctly identifying between 2 and 5 percent of the TOI.

6.6.7.1. Statistical classifiers are automated processes that use one or more feature parameters to make a quantitative decision as to whether an anomaly is or is not a TOI. The key attributes of statistical classifiers include one or more of the following:

a. Statistically characterize attributes and create group associations, or clusters.

b. Input features include all three primary axis polarizabilities x N time gates.

c. Include machine learning (e.g., support vector machines, neural networks).

d. Are trained on prior target information to attach labels to the feature clusters.

e. Provide explicit probabilities that the anomaly is a target of interest.

f. Accommodate many attributes and data dimensions (Keiswetter, 2010; Bell, 2011).

6.6.7.1.1. The key steps in developing classifier rules for a statistical classifier are to:

- locate expected munitions item signatures in feature space;

- sample the feature space (i.e., collect training data) for regions around features that are likely munitions (e.g., $\beta_1$ is much larger than $\beta_2$ and $\beta_3$, and $\beta_2$ is approximately equal to $\beta_3$) and for other feature clusters; and

- train the classifier with labeled features in order to set the decision boundary to exclude targets that are not of interest (e.g., high confidence clutter) (Bell, 2011). See Section 6.6.6 for further discussion of training a classifier.

6.6.7.1.2. The performance of statistical classifiers greatly depends on the feature parameters used in the classifier. The qualified geophysicist must determine which feature parameter(s) work best on a given site since no single classifier works best on all sites. After the geophysicist has selected the feature parameter(s) that will be used in the classifier, a boundary, or threshold, must be chosen to differentiate between those anomalies that the geophysicist has a high confidence are TOIs and the rest of the anomalies. For a statistical classifier, the threshold is based on the probability that the anomaly is a TOI, and the goal is to select all of the anomalies that cannot be due to TOIs. The initial threshold is selected such that it excludes the interpreted non-TOI, and the final threshold is selected after adjusting the threshold to account for unexpected variability in the feature parameter estimates (Keiswetter, 2008). The final threshold should be re-evaluated and adjusted, as necessary, through a feedback process as the anomalies are excavated.

6.6.7.2. Library matching classifiers compare the extracted features against a signature library for known munitions types and other TOIs (e.g., ISOs). The key attributes of library matching classifiers are that they compare polarizability against a library of signatures for expected munitions and other training objects.

6.6.7.2.1. The signature matching within library matching classifiers quantifies the degree to which the extracted features within the dataset match those for known targets of interest. One issue with using library matching classifiers is that the EMI signature for a single munitions type may be nominally different for different subtypes of the munitions, depending on inversion, errors due to noise, and whether the munition is damaged. To account for these variations, the library matching procedures should allow for some variability in the modeled features in order to maximize the effectiveness of the classifier.

6.6.7.3. Once the anomaly classifier has been refined via the evaluation of training data, the geophysicist should classify anomalies into one of three categories of anomalies. The PDT should excavate all anomalies that could be potential TOIs and should not excavate the anomalies that are not TOIs unless an unknown type of UXO is encountered during the intrusive investigation and the feedback loop analysis indicates some of these anomalies originally should have been classified as TOIs.

6.6.7.3.1. Category 1. The anomaly classifier indicates that the anomaly is a TOI. All anomalies within this category should be dug.

6.6.7.3.2. Category 2. The anomaly classifier can't determine whether these anomalies are or are not TOIs. Due to the uncertainty in the classifier results, anomalies within this category may or may not be excavated. Decisions to dig these anomalies will be based on one or more of the following parameters:

- Fit error
- Distance from flag
- Distance from the array center
- Axial symmetry
- Library metric within defined range
- Weak signal
- Noisy polarizations
- DGM anomaly parameters

6.6.7.3.3. Category 3. The anomaly classifier was successful, and the anomaly is identified as non-TOI. Because the geophysicist has a high confidence that these anomalies are not potential TOI, no Category 3 anomalies are required to be excavated. If, however, unknown munitions types are identified during the intrusive investigation, the feedback loop analysis (as discussed in Section 6.6.10) should be performed to evaluate whether other potential anomalies have similar features to the newly identified UXO to determine if some of the Category 4 anomalies should be placed on the dig list.

6.6.8. Populate Dig Lists. Once the PDT has collected the training data to determine the nature of the anomalies within each of the feature clusters (i.e., once feature labels are obtained from the training data), the geophysicist should refine and finalize the classifier to ensure that all TOIs are recovered. All TOIs, which may include ISO QC blind seeds, are placed on the dig list. The order in which anomalies are placed on the dig list is important because the success of the classifier is assessed in part as a function of its predictive power. Dig lists are prioritized in the following manner: 1st, anomalies that cannot be analyzed as discussed in Section 6.6.7 are placed at the top of the dig list. Next, anomalies are sorted in order of the confidence the analyst has that the anomaly is a TOI, highest confidence first, lowest confidence last. Although TOIs are based on classifier rules, it is important to include as much information as is reasonable on the dig lists, to include any information needed to facility anomaly reacquisition, resolution and the feedback process. At a minimum the following information should be included: the detection peak response from the DGM survey, predicted depth from the inversion, and predicted anomaly parameters from the classification process (e.g., munitions type or anomaly group such as small, medium or large). Although TOIs will be based on the classifier rules, it is important to include DGM peak responses from the DGM survey and any other required parameters are placed on the dig list to aid in the anomaly resolution process. The classification methodology and rationale for inclusion of the anomaly on the dig list should be documented completely and reviewed by government geophysicists for compliance with geophysicist needs and project objectives. Figure 6-33 presents an example of the classification rationale and decision logic for determining whether an anomaly should be placed on a dig list.

6.6.9. Anomaly Resolution Process. The term anomaly resolution is used in reference to all activities related to reacquiring previously detected anomalies and/or excavating anomalies to the point they are unambiguously explained. There are three key aspects to anomaly resolution: anomaly reacquisition, anomaly excavation (including reporting dig results), and post-dig verification sampling.

6.6.9.1. Anomaly reacquisition is a critical element of DGM systems because this task must physically match anomalies on dig lists with their sources. This is achieved by using a method to navigate to the selected location, reproducing a signal at that location and placing a plastic pin flag and/or painting the ground surface above the reacquired source. The challenge is in matching selected anomalies with their true sources because those sources often are buried or otherwise obscured from view. In cases where an anomaly being sought has no other nearby anomalies or other sources of interference and the anomaly has a high SNR, this task can be fairly straightforward and have little likelihood of reacquiring the wrong source. In other circumstances, reacquiring the originally interpreted anomaly could be difficult, and reacquisition procedures would need to be explained in great detail. The following are critical factors to consider in planning and performing anomaly reacquisition procedures. All procedures should be fully described in the UFP-QAPP or SOPs and have QC processes to ensure the project’s anomaly reacquisition performance metrics are met.

6.6.9.1.1. In order to ensure that the correct anomaly was reacquired and excavated, the geophysicist must establish performance metrics to monitor the offsets between the interpreted and reacquired target locations (see Chapter 11 for more details on establishing performance metrics). Key questions that the geophysicist should ask include the following:

- What is the accuracy of the reported dig list coordinates, and what is the accuracy of the navigation system used to reacquire those points?

- What is the allowable distance between reacquired location and interpreted location?

6.6.9.1.2. Often the sum of errors in the DGM positioning is less than 0.5 m and the accuracy of navigation tools used to reacquire anomalies typically is between 2 and 30 cm. The accuracy of the interpreted coordinates can be even greater when closely detected anomalies are aggregated together. Therefore, search radii for locating the true anomaly source must factor the sum of all potential positioning and reporting errors in interpreted anomaly locations. It has been observed that inversions from advanced sensors produce x, y, and z estimates that can have an accuracy of approximately 5 cm (Andrews et al., 2011).

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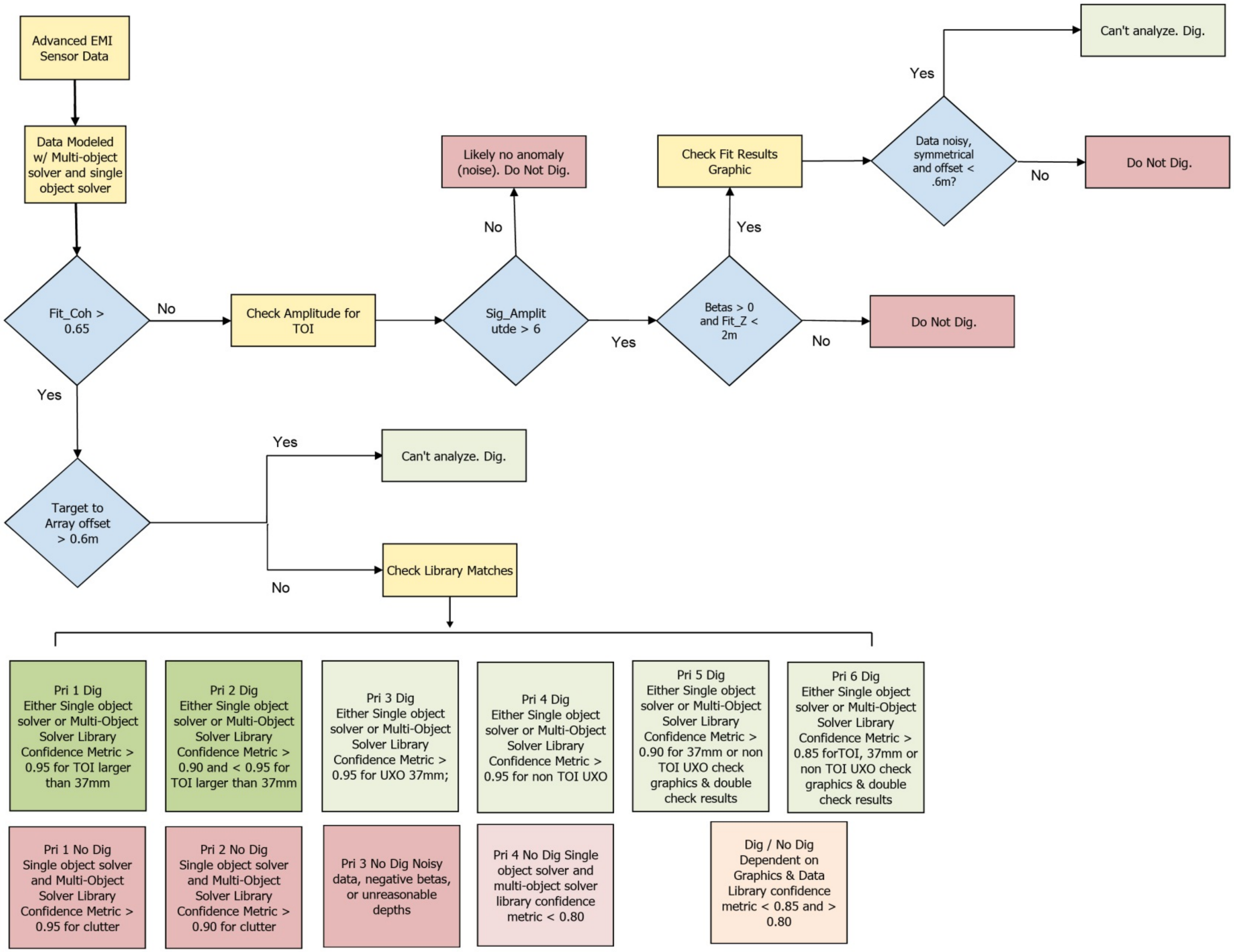



Figure 6-33: Example Classifier Decision Logic

6.6.9.1.3. If the reacquisition team will be able to reproduce the originally interpreted response, what are the tolerances for the reproduced response? Anomalies detected in dynamic DGM surveys often have detected amplitudes that are less than those observed during reacquisition. Further, if weaker signals are present in proximity to a selected anomaly location, criteria must be established to either flag all nearby anomalies regardless of reacquired amplitude or reacquire all anomalies meeting project-specific criteria, typically peak amplitude. Criteria also must be established for minimum and maximum allowed signal strength of reacquired anomalies; any location where a source cannot be located within those criteria should be labeled as an ambiguous reacquisition result.

6.6.9.1.4. If the reacquisition team will not be able to reproduce the originally interpreted response, what measures are used to provide confidence the correct anomaly is actually reacquired? What constitutes an ambiguous reacquisition result and what procedures are in place to resolve such results? Reacquisition procedures that use geophysical systems not having the same detection capabilities as those used to collect the original data must have very specific procedures in place to prevent the wrong anomaly from being reacquired. Typical criteria to include in such procedures are limits on how far a suspect source location can be placed from the originally interpreted location, requiring all detectable anomalies within the total error radius be flagged for excavation, requiring that all dig results be reviewed by the interpreting geophysicist or other designated geophysical personnel, requiring a percentage of all anomalies be verified using the original geophysical system during post-excavation verification, and including the requirement to return to all ambiguous reacquisition results.

6.6.9.2. In order to resolve all anomalies on the dig list and pass QA/QC, the UXO dig team must clear the entire footprint of the DGM anomaly. In the past, UXO technicians may have cleared only a 3-foot search radius around an anomaly; however, this could lead to leaving munitions in the ground. Many geophysical anomalies are due to multiple subsurface objects and can have a large footprint. Clearing only to the 3-foot radius may mean that all sources of the anomaly are not excavated. The anomaly resolution process should ensure that the anomaly size is removed to below the anomaly selection threshold for the entire anomaly footprint to avoid leaving behind potential munitions.

6.6.9.3. Anomaly excavation routines are covered under the intrusive operations section(s) of the UFP-QAPP. This topic is included herein as it pertains to meeting project objectives of unambiguously resolving geophysical anomalies. The disposition and final location details of each anomaly normally are recorded on the final dig sheets, which should be submitted to all PDT members IAW project needs and/or SOW/PWS requirements. The reported dig results should be reviewed by the interpreting geophysicist or other designated geophysical personnel, and those personnel must have authority to require additional reacquisition and/or excavation activities be performed for all anomalies having characteristics that are not unambiguously explained by the reported dig results. These reviews can include automated searches to compare reported findings with predetermined threshold criteria. It is important that dig results are reported in sufficient detail so they can be compared to geophysical data in order to facilitate an evaluation of whether or not the anomaly was resolved. For example, the dig team can be required to report an anomaly source as large (greater than 5 pounds or greater than 18 inches in length), medium (between 1 and 5 pounds or between 6 to 18 inches in length), or small (less than 1 pound or less than 6 inches in length). Automated routines then can be developed to compare those reported results to preset anomaly criteria of large, medium, or small items using predetermined ranges. Tests where a match is not made between reported finding and anomaly characteristics would be flagged for further review by qualified geophysicists. Any combination of anomaly characteristics can be developed into any number of tests to compare dig results with various anomaly characteristics. Software tools (e.g., relational databases, Geosoft's UX-Process) can aid in simplifying these tests.

6.6.9.4. Post-dig anomaly resolution sampling is conducted after intrusive investigations to verify that the source of the anomaly has been removed during the intrusive investigation. Anomaly resolution sampling should be completed after the intrusive investigation within a sector (or lot of data) has been completed. The original geophysical instrument used to identify anomalies, or one that performs better than it, should be used to verify that the anomalies have been resolved.

6.6.9.4.1. Table 6-6 presents a summary of the number of anomalies that require post-dig anomaly resolution given a certain lot size (e.g., number of anomalies) and a desired confidence level that less than a certain percentage of anomalies remain unresolved after the investigation. The geophysicist must choose the confidence level that is most appropriate for the particular site; however, some general defaults are provided for RIs and RAs. Unresolved anomalies are anomalies for which a signal remains after the excavation without a complete rationale for the remaining anomaly presence. In addition to Table 6-6, the PDT can use VSP's Anomaly Compliance Sampling module to calculate an exact number of anomalies that need to be re-examined for anomaly resolution verification for specific lot sizes.

6.6.9.4.2. Post-Dig Anomaly Verification Resolution Example. The PDT is performing a removal action at MRS Zulu. UXO was found at MRS Zulu during the RI, and the PDT decided to use the default confidence level in Table 6-6 (90% confidence < 1% unresolved). Each lot represents 1 days' worth of DGM data collection and anomalies. The number of anomalies and the number of anomalies that required post-dig verification sampling for the first 4 days' worth of data collected are listed below:

- Lot 1: 73 anomalies, 66 of which are verified post-dig Lot 2: 143 anomalies identified, 115 of which are verified post-dig
- Lot 3: 343 anomalies identified, 168 of which are verified post-dig
- Lot 4: 111 anomalies identified, 98 of which are verified post-dig

6.6.10. Feedback Process. The geophysicist should employ a feedback process throughout the intrusive investigation in order to verify the effectiveness of a classifier and to determine if additional types of targets of interest are present on a site that indicates revisions to the classifier may be required. If UXO is found at an anomaly that was thought not to have been a TOI, it is likely that the classifier needs to be modified to be more conservative. In addition, the feedback process should evaluate whether seed items and recovered UXO are within the sensor curves after factoring for noise. If the responses associated with recovered UXO or seed items are below the sensor response curves, this may indicate there was more noise in the DGM survey than anticipated and the anomaly selection threshold may require adjustment.

Table 6-6: Acceptance Sampling \ for Anomaly Resolution

| Confidence Levels | Lot Size (number of anomalies) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **50** | **100** | **200** | **500** | **1000** | **2000** | **5000** | **10,000** |
| 70% Confidence < 10% unresolved[a] | 11 | 11 | 12 | 12 | 12 | 12 | 12 | 12 |
| 80% Confidence < 10% unresolved | 14 | 15 | 15 | 16 | 16 | 16 | 16 | 16 |
| 90% Confidence < 10% unresolved | 18 | 20 | 21 | 22 | 22 | 22 | 22 | 22 |
| 95% Confidence < 10% unresolved | 22 | 25 | 27 | 28 | 29 | 29 | 29 | 29 |
| 70% Confidence < 5% unresolved | 17 | 21 | 23 | 23 | 24 | 24 | 24 | 24 |
| 80% Confidence < 5% unresolved | 21 | 27 | 30 | 31 | 31 | 32 | 32 | 32 |
| 85% Confidence < 5% unresolved | 23 | 31 | 34 | 36 | 37 | 37 | 37 | 37 |
| 90% Confidence < 5% unresolved[b] | 27 | 37 | 41 | 43 | 44 | 45 | 45 | 45 |
| 95% Confidence < 5% unresolved | 31 | 45 | 51 | 56 | 57 | 58 | 59 | 59 |
| 80% Confidence < 1% unresolved | 40 | 80 | 111 | 138 | 144 | 154 | 158 | 159 |
| 85% Confidence < 1% unresolved | 43 | 85 | 123 | 158 | 172 | 181 | 186 | 187 |
| 90% Confidence < 1% unresolved[c] | 45 | 90 | 137 | 184 | 205 | 217 | 224 | 227 |
| 95% Confidence < 1% unresolved | 48 | 95 | 155 | 225 | 258 | 277 | 290 | 294 |

Note: Values within the table show the number of anomaly locations chosen for intrusive investigation that require post-dig anomaly verification. All anomalies within the lot must be shown to be resolved to meet confidence levels (accept on zero).

a Default for RIs where UXO or DMM have been recovered

b Default for RIs where no UXO or DMM have been recovered

c Default for RA

These default values have been used in the past; however, they may not be appropriate for all sites and land uses. The PDT must choose the confidence levels and % unresolved values that meet the project objectives.

6.7. Geophysical Systems Verification Planning Considerations.

6.7.1. Introduction. Verification of a geophysical system's performance, both analog and digital, is a critical component for ensuring that data DQOs and data needs are met on MR projects. The GSV process, which consists of an IVS and a blind seeding program within the production site, should be implemented IAW the Final Report Geophysical System Verification (GSV): A Physics-Based Alternative to Geophysical Prove-Outs for Munitions Response (Final GSV Report, ESTCP, 2009) as well as with this EM. The Final GSV Report may be downloaded at http://www.serdp.org/Featured-Initiatives/Munitions-Response-Initiatives/Geophysical-System-Verification, and tutorials for the GSV process are provided at http://www.serdp.org/Tools-and-Training/Munitions-Response/Geophysical-System-Verification. GSV is only for DGM of well-characterized instruments; however, as discussed in Section 6.6.2.4, the Sensor Response Curve Calculator may be used to generate response curves for additional instruments or for munitions that were not included in the NRL Reports listed in Section 6.6.2.4. The qualified geophysicist is responsible for ensuring that the geophysical prove-out (GPO) or GSV meets the requirements of the project and that the implementation meets the standards set out within the project's UFP-QAPP.

6.7.1.1. The GSV is the preferred method for verification of digital geophysical systems. The geophysicist may determine there is a requirement for a GPO if the DGM or analog performance is unknown or responses cannot be predicted. Because of this fact, planning considerations for both the GPO and the GSV are presented in the following subsections. If a GPO is used instead of the GSV, the geophysicist still should implement a blind seeding program following GSV protocols in the production geophysical investigation area as an additional means to verify that geophysical data meet the project's DQOs.

6.7.1.2. A GPO is required when the DGM instrument is a black box, the sensor response can't be predicted, or the geophysicist cannot determine how to select anomalies for a particular sensor. The anomaly characteristics for some digital geophysical instruments cannot be predicted. If the geophysicist selects such an instrument, then the instrument should be evaluated at a GPO to estimate the detection depth capabilities of the instrument prior to beginning the removal action. The GPO should be conducted IAW Section 6.7.3 and the Interstate Technology Regulatory Council's (ITRC's) Geophysical Prove-Outs for Munitions Response Projects (2004). In addition to the GPO, the geophysicist should implement the GSV process, including a limited IVS and blind seeding within the production area, to ensure that the geophysical system meets the project's DQOs.

6.7.1.3. The verification of analog geophysical instrument should be performed on an instrument test strip similar to an IVS. The verification process should include using an audiometer to test the UXO technician's ability to hear the response to objects within a known or constant magnetic field. Daily UXO technician instrument functionality tests must be implemented. These tests, however, are not considered part of the GSV process because they lack a recorded response and the rigorous evaluations made for digital systems. Blind seeding within the production area must be performed.

6.7.1.4. The following paragraphs describe the PDT's responsibilities during the GSV. The GSV consists of two components: the IVS and a blind seeding program within the production site. The overarching goals of the GSV are to confirm system performance during data collection on the production site to ensure that performance metrics or MQOs are met. The following paragraphs discuss the planning considerations for the IVS and the blind seeding program. The GSV requires that the geophysicist plans to use a well-characterized sensor (i.e., one for which sensor response curves exist) or an instrument for which sensor response curves can be generated to demonstrate the DGM sensor is functioning IAW the expected response characteristics, well-characterized test objects (e.g., standard munitions items, ISOs). The GSV also requires that digital data collection be employed during the project (e.g., EM61-MK2, G-858). Response curves for the EM61-MK2 for standard munitions items and ISOs are available in NRL Report NRL/MR/6110--08-9155: EM61-MK2 Response of Standard Munitions Items and NRL Report NRL/MR/6110--09-9183: EM61-MK2 Response of Three Munitions Surrogates, respectively. Both of these reports are available from the Internet link provided above for the Final GSV Report. NRL also has calculated theoretical response curves for standard munitions items for magnetometers; they are available in NRL Report NRL/M/6110--12-9385 and can be downloaded from http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA557775. This report includes tabulated magnetometer response curves and scaling factors for changes in orientation and strength of the Earth's magnetic field due to location, as well as discussion of the difficulties encountered due to remanent magnetization.

6.7.2. GSV Planning Considerations. This section discusses some of the planning considerations associated with GSV.

6.7.2.1. IVS. The purpose of the IVS is to ensure the DGM instrument functionality prior to collecting data within a production area. The IVS also may be used to determine the RMS background noise at the site to aid in anomaly selection, as discussed in Section 6.6.2. In addition, the IVS is used to quantify the expected errors in recorded response due to variations from several factors listed below. Blind seeding results within the production area also should be compared to the initial and daily IVS surveys to ensure instrument functionality.

6.7.2.1.1. Various factors affect the recorded response of DGM instruments. Detailed discussions of the variations in response can be found in the Final GSV report (ESTCP, 2009). Variations due to individual factors should be quantified to the extent possible during the IVS to enable a determination of the approximate total error bars associated with the theoretical response curves. For example, several factors affecting the recorded response from seed items include, but are not limited to, the following:

- Location and Depth
- Along-Track Offset
- Instrument Bounce
- Seed item Orientation
- Remanent Magnetization

6.7.2.1.1.1. Although response curves for three sizes of ISOs have been documented by NRL, studies to evaluate the reproducibility of response from identical-sized ISOs from different manufacturers show that there is some variability in response. Figure 6-34 shows the stacked EM61-MK2 response for small ISOs from multiple manufacturers buried at three different depths in the vertical, horizontal along-track (i.e., inline), and horizontal across-track (i.e., crossline) orientations. The solid lines on Figure 6-34 represent the theoretical responses for the most and least favorable orientations presented in NRL Report NRL/MR/6110--09-9183. Note that the variation in response within individual orientation and depth can be approximately a factor of 2.

6.7.2.1.1.2. It is also important to note that the measured response for the horizontal across-track (i.e., crossline) orientation is less than the theoretical response. This is due to the averaging function intrinsic to the EM61-MK2. The findings represented in Figure 6-34 emphasize the importance of measuring the variation of response for the seed item and accounting for the potential errors of the seed item since the responses measured in the IVS are one of the key variables factors in instrument function verification. See Inert Ordnance and Surrogate Item Anomaly Evaluation for detailed information regarding the variability of EM61 sensor response to common seed items and select munitions (USAESCH, 2011).

6.7.2.1.2. Selection of the IVS site(s) should be based upon the technical and site-specific considerations developed and finalized during the TPP process and/or PDT meetings. Factors to be considered include:

- similarity of terrain, vegetation, and geologic conditions to the production site;
- proximity to the project site;
- isolation from overhead power lines, radio transmitters, underground utilities, etc.;
- convenient access;
- likelihood that area will remain undisturbed during period of use;
- ROEs;
- possibility of pre-existing subsurface UXO; and
- need to excavate known and/or unknown anomalies.

6.7.2.1.3. The following sections identify the key components of the IVS design. More detailed guidance on these factors can be found in the Final GSV Report (ESTCP, 2009).

6.7.2.1.3.1. <u>Pre-Seeding (Background) Geophysical Mapping</u>. After a location has been selected and the surface prepared, a pre-seeding geophysical survey will be performed in order to determine and document baseline geophysical conditions at the location. The background survey also may be used to identify potential subsurface TOIs within the IVS footprint, which may or may not be cleared prior to seeding the IVS.

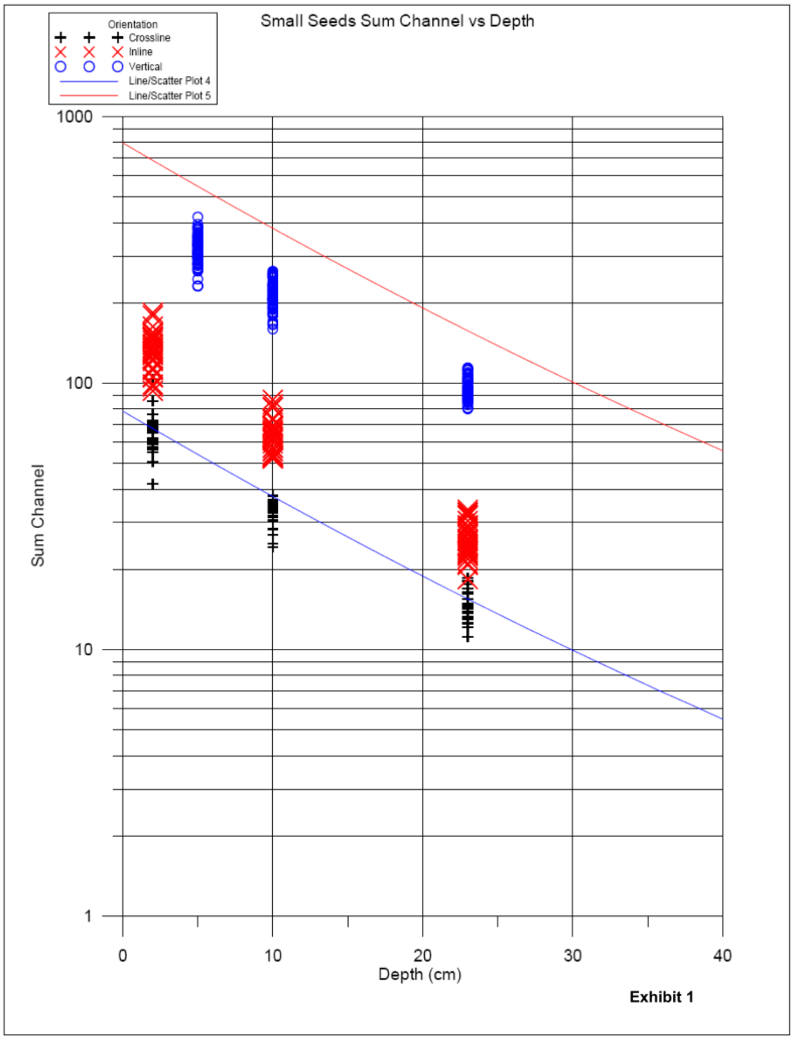



Figure 6-34: Example of the Variation in Actual EM61-MK2 Summed Channel Responses from Small ISOs from Multiple Manufacturers Plotted as a Function of Depth (USAESCH, 2011). (Solid lines represent the theoretical responses for the most and least favorable orientations presented in NRL Report NRL/MR/6110-09-9183. Note that the significant variations in response seen for each orientation and that the actual measured response for the horizontal across track (e.g., cross-line) is often less than the theoretical response curve for the same orientation.)

6.7.2.1.3.2. Size and Configuration. In general, the IVS is approximately 100 feet long and approximately 10–15 feet wide. The IVS consists of a centerline (under which the seed items will be placed), lines on either side of the centerline at the planned line spacing, one line at half of the planned line spacing, and one line to measure the site noise. The noise measurement line should be placed far enough away from the seed items to ensure the sensor does not detect the seed items. If the particular investigation contains numerous MRSs spread over a large distance and areas with potential variations in background response, it may be necessary to install more than one IVS. In this instance, the geophysicist may use either one IVS configuration that moves from MRS to MRS as the work progresses or multiple IVSs installed and maintained at each site during the duration of the project. Multiple IVSs should be installed when there is significant difference between sites (e.g., varying noise regimes due to cultural and/or geologic noise) or to support logistics of IVS tasks on large sites or sites that use multiple instruments.

6.7.2.1.3.3. Seeded Items. The geophysicist should develop a listing of ISOs to be seeded within the IVS during the TPP meetings and document them within the UFP-QAPP. A single ISO seed item is sufficient to demonstrate and document instrument functionality; however, more may be used if deemed necessary by the geophysicist.

6.7.2.1.3.4. Depths and Orientation. The seed items should be buried at specified depths and orientations. The seed items must be buried at depths that ensure 100% detection. The recommended depth of seed item burial is five to seven times the diameter of the ISO, and the orientation should be horizontal and/or vertical to facilitate comparisons to the theoretical response curves. After the seed items are buried, care should be taken to blend excavation locations back to natural conditions.

6.7.2.1.3.5. Cultural Interference. Because the IVS is a test of an instrument's functionality, the IVS should be placed within an area that does not have significant cultural interference. If the production site has multiple noise regimes (e.g., one area with quiet background noise and one area with cultural noise from overhead power lines), the geophysicist may place a background noise line in multiple areas to estimate the RMS noise for each noise regime on the site. This approach is particularly useful for varying the anomaly selection threshold across the site if the geophysicist is basing the anomaly selection criteria on some multiple of the RMS noise.

6.7.2.2. Blind Seeding. The goal of blind seeding within the production area is to evaluate the dynamic detection repeatability (i.e., response) of the geophysical sensor and dynamic positioning repeatability (i.e., offset) and to test anomaly resolution. The blind seed items should be ISOs or inert munitions for which response curves exist to enable their measured responses in the field data to be compared to predicted response levels. In general, the seed item that will stress the geophysical system the most (i.e., the smallest ISO or munitions anticipated at a site) should be used as the blind seed item. Significant guidance on the blind seeding process is included in the Final GSV Report and not repeated here (ESTCP, 2009); however, some additional guidance is provided below.

6.7.2.2.1. Blind Seeding Frequency. The geophysicist should determine during the TPP sessions and outline within the UFP-QAPP the frequency at which blind seeds will be placed within the production work site. Chapter 11 provides additional guidance on blind seeding frequency, evaluation, and pass/fail criteria. At a minimum, blind seeds should be placed in sufficient frequency to determine the quality of each production unit. The production unit could be either each grid or transect or each dataset. Placing blind seeds on transects that are not predetermined (i.e., not staked out by a surveyor) could be difficult to detect. Blind seeding on transects that are not dug (i.e., transects on which anomalies will be counted but not dug) is not required. Additional blind seed items should be placed in areas that may present a detection challenge (e.g., adjacent to trees, in rough terrain, within areas with high cultural noise).

6.7.2.2.2. Locating Blind Seeds. Blind seed item depths and locations need to be measured as precisely as possible to enable accurate evaluation of the dynamic response repeatability and dynamic positioning repeatability performance metrics, respectively. The most accurate depth measurement method is likely a simple measuring tape, which should be used to locate the center of the seed item as a depth below ground surface. For determining the horizontal location of the blind seed item, a RTK DGPS should be used to locate the centroid of the seed item where feasible. Where RTK DGPS is not feasible (e.g., within heavily forested areas), other positional methods should be employed (e.g., robotic total stations, distance from a known location). It is critical that the geophysicist develops an accurate approach to measuring the depth and location of the blind seed items to make sure they enable accurate assessments of DGM production data. Small errors in depths will result in relatively large variations in sensor response.

6.7.2.2.3. Blind Seeding Performance Standards. Blind seed item detection MQOs are evaluated using the dynamic response repeatability and dynamic positioning repeatability performance metrics. The dynamic response repeatability test compares the response of the blind seed item and its associated error bar with the theoretical response curves for the seed item. Figure 6-35 shows an example of such a comparison (ESTCP, 2009). The measured response for each blind seed item should be plotted on the graph as the project progresses to document that blind seed items are meeting the project MQOs. For the dynamic positioning repeatability test, the interpreted target locations for blind seed items should be compared to the actual blind seed item location. The offset, or deviation, between these two locations should be plotted on a control plot diagram similar to Figure 6-36 to show the offsets for all blind seed items placed within the production site. Chapter 11 provides additional guidance on the standard metrics that should be applied for each of these tests.

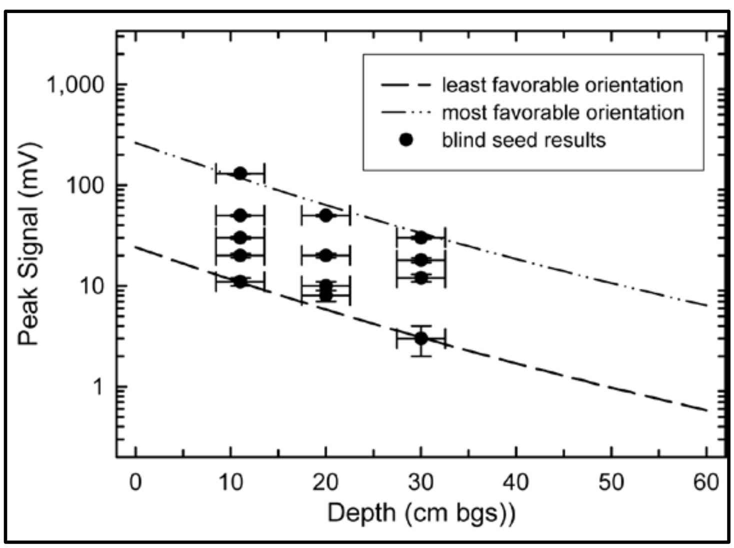



Figure 6-35: Comparison of Blind Seed Response with Their Error Bars to the Theoretical Response Curves for the Most and Least Favorable Orientations (ESTCP, 2009)

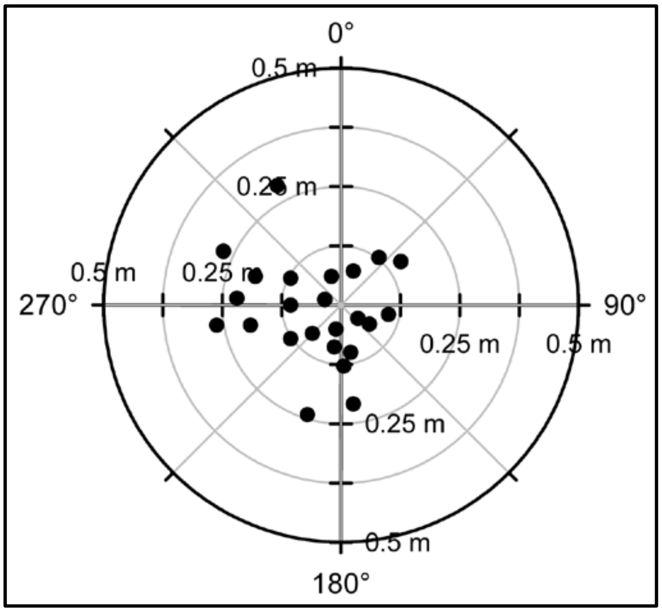



Figure 6-36: Comparison of the Offset Between the Known Location of Blind Seed Items and the Interpreted Target Location (ESTCP, 2009)

6.7.2.3. Guidance. Refer to the following Web sites for further details and guidance on and examples of the GSV process:

a. http://www.serdp.org/Tools-and-Training/Munitions-Response/Geophysical-System-Verification

b. http://symposiumarchive.serdp-estcp.org/symposium2009/sessions/sc-1.html

6.7.3. GPO Planning. As discussed above, a GPO should be used when a DGM sensor is not well characterized and sensor response curves can't be generated. The following paragraphs describe the PDT's responsibilities during the GPO process. The GPO can be a complex and time-consuming effort; the PDT must collaborate to confine the scope of the GPO to basic project needs.

6.7.3.1. GPO Purpose. There can be many purposes for a GPO, as follows. In the GPO Plan, it is necessary to state the prove-out objectives and to describe how these objectives will be met.

6.7.3.1.1. Determine if a particular geophysical system meets detection requirements.

6.7.3.1.2. Determine the optimum system configuration and SOPs.

6.7.3.1.3. Demonstrate detection depth capabilities. This objective is not recommended because a large population of data from national test sites and other GPO sites are available. A more reasonable objective would be to demonstrate that the system is meeting typical detection performance capabilities for a given TOI and/or that the project objectives, as stated in the PWS/SOW, are technically feasible.

6.7.3.1.4. Assure contractor compliance with the contract. Test plots provide a safe area for the geophysical investigation team to develop site-specific field and evaluation procedures necessary to demonstrate compliance with project requirements.

6.7.3.1.5. Evaluate the data collection methods, data transfer method(s), and data transfer rates.

6.7.3.1.6. Establish site-specific geophysical data needs and site-specific data quality measures and protocols for all work tasks involving geophysics and all work tasks that use geophysical data. The GPO provides the geophysicist the opportunity to describe how they define "good data" for sensors that currently are undefined or not well defined. Elements that affect data usability often will focus on coverage, measurement densities (along-track and across-track measurement intervals), and accuracies or precisions of reported measurement locations. These elements often assume instrument function checks were successful. For example, GPO results for a specific project sensor line assume that spacing be 0.8 m (typical) and not exceed 1 m, that along-track measurement intervals be 25 cm (typical) and not exceed 80 cm, and that positioning accuracy is 20 cm (typical) to achieve detection requirements.

6.7.3.1.7. Establish site-specific anomaly characteristics for selection criteria.

6.7.3.1.8. Demonstrate anomaly resolution procedures to assure contractor SOPs achieve both project requirements and QC and QA requirements. Many anomaly resolution procedures use geophysical systems with different detection capabilities, and the contractor must demonstrate their SOPs account for such differences. See Section 6.6.9 for more information on the topic of anomaly resolution. GPO sites located outside of project boundaries are best suited to demonstrate all anomaly resolution procedures, including excavation.

6.7.3.2. Factors in GPO Site Selection. Selection of the GPO site(s) should be based on the technical and site-specific considerations developed and finalized during the TPP process and/or PDT meetings. Factors to be considered include:

a. similarity of terrain, vegetation, and geologic conditions to actual field conditions;

b. proximity to the project property;

c. isolation from overhead power lines, radio transmitters, underground utilities, etc.;

d. convenient access;

e. likelihood that area will remain undisturbed during period of use;

f. ROEs;

g. possibility of pre-existing buried UXO; and

h. need to excavate known and/or unknown anomalies.

6.7.3.3. Factors in GPO design. The geophysicist should consider numerous variables when planning a GPO, which include, but are not limited to, pre-seeding geophysical mapping, the size and configuration of the GPO, and data collection variables (e.g., instrument height, instrument orientation, measurement interval). Further guidance is available in the ITRC's Geophysical Prove-Outs for Munitions Response Projects, which can be downloaded at http://www.itrcweb.org/Documents/UXO-3.pdf.

6.8. Special Considerations for Planning Geophysical Investigations.

6.8.1. Survey Coverage Considerations. Survey coverage issues may arise when competing project objectives are defined within the framework of the project's DQOs. As an example, survey coverage issues will arise in situations where a project objective to not disrupt protected or endangered species is stated, but complying with that objective restricts vegetation clearance and, therefore, limits or precludes geophysical mapping. Other situations may arise where accessibility is hindered by terrain conditions, cultural interferences, or other natural or manmade impediments. Another common conflict arises in resources required to meet some stated objectives, such as wanting all detected anomalies investigated during a characterization project. Often the resources required and costs associated with such an objective will be very high, but the value-added to the characterization outcome would be minimal in doing so.

6.8.1.1. Sometimes compromises can be reached, such as using less sensitive detectors that require less vegetation removal and, therefore, minimize impact to native or listed species or using anomaly selection schemes that provide representative samples of each different anomaly type. Sometimes no compromise can be reached, and either the areas in question will be left unmapped or the requisite steps will be taken to make all areas accessible to the mapping and response technologies.

6.8.1.2. Issues impacting survey coverage should be identified as early as possible during planning phases. If none are immediately identified during planning but the potential exists for such issues to arise, it may be beneficial for the project team to plan for such cases and include any such plans in the project UFP-QAPP. In the event compromise strategies are used, it is critical that all project team members completely understand the benefits and limitations of the compromise strategy in terms of what TOIs likely will be detected and what TOIs may go undetected. The characterization and excavation needs listed in geophysical investigation strategies can help in identifying and resolving survey coverage issues during project planning.

6.8.2. Managing False Positives, No Contacts, "Hot Rock" Contacts, and Geology Contacts. Many geophysical instruments detect anomalies associated with geology and cultural features, such as power lines. When such anomalies are repeatable, they usually are associated with geologic sources, also referred to as "hot rocks." When the sources are not repeatable or are detected with highly varying signal strengths, they usually are associated with cultural features (such as power lines) or vehicles passing by. In many cases, small TOIs near the surface or large TOIs buried deep can have anomaly characteristics similar to anomalies that could be associated with local geology. In other instances, TOIs will almost never have geophysical responses similar to local geology but may have interference from power lines present over or near a project site. Such anomalies usually can be interpreted as cultural interference; however, on occasion, these may manifest themselves in geophysical data with anomaly characteristics similar to those for TOIs. For any project where the field teams may encounter any of these situations, the contractor should develop and submit for government concurrence a plan for accepting and/or rejecting the reported findings for anomalies that have characteristics of geology/cultural features and UXO. Normally, such plans should be confined to managing low-amplitude and/or small spatial extent anomalies reported as false positives, no contacts, or geology (hot rock). These types of anomalies are more prone to have response characteristics that could be associated with either a metallic source or some other noise source. This plan should define specific metrics for accepting or rejecting anomalies in this category, and the plan should identify quantity thresholds that will trigger a re-evaluation of the project methodologies to address increased or unexpected high quantities of false positives and/or no contacts

# CHAPTER 7

## Munitions Constituents Characteristics and Analytical Methodologies

7.1. Introduction. MC are any materials originating from UXO, DMM, or other military munitions, including explosive and non-explosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions (10 U.S.C. 2710(e)(3)). This chapter provides an overview of the environmental chemistry of MC and the approaches and techniques for their analysis. It should be used as background information in conjunction with the information on MC sampling considerations and approaches provided in Chapter 8. Chemical/physical properties of MC and major transformation products are provided in Appendix D.

7.2. Sources of Munitions Constituents in Munitions.

7.2.1. Figure 7-1 illustrates the typical components of high explosive (HE) munitions. The primary sources of MC, based upon the weight composition of typical munitions, are the projectile body, cartridge case, the filler, and the propellant. The minor sources of MC include the fuze, the primer, and the booster.

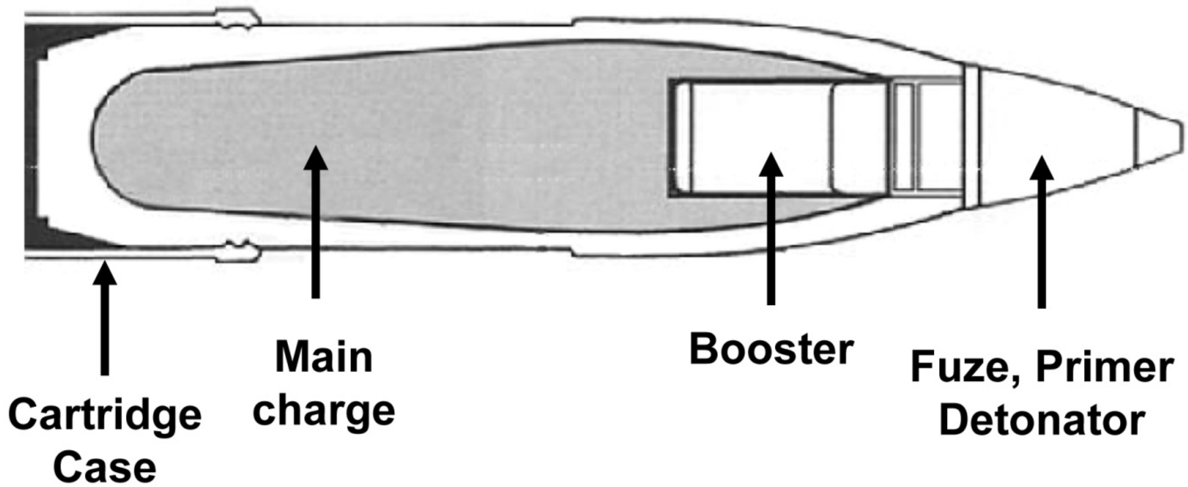



Figure 7-1: Sources of MC in Munitions

7.2.2. Munitions fillers may include a variety of MC, including secondary explosives (also found in boosters), chemical agents (including incapacitating agents and simulants), riot control agents, pyrotechnics (e.g., incendiaries, tracers, smokes, obscurants), and miscellaneous other fillers. Propellants include black powder, nitrocellulose (NC), nitroglycerine (NG), nitroguanadine (NQ), and perchlorate. Munitions cases and shells typically are composed of metals. Primers and fuzes contain primary explosives.

7.3. Overview of Munitions Constituents Analytical Laboratory Instrumentation.

7.3.1. Overview of MC Analyses. Samples collected for MC analyses typically are shipped to fixed laboratories. Field analytical methods may be used; however, for decision quality data, project teams should establish an appropriate percentage of these analyses to be confirmed by a fixed laboratory based on project-specific DQOs.

7.3.2. Analytical Instrumentation. The analytical methodologies that are used to detect MC in environmental samples require the use of one or more of the following types of analytical equipment:

7.3.2.1. High performance liquid chromatography (HPLC or LC)

a. Coupled with ultraviolet spectrometry (LC/UV)

b. Coupled with mass spectrometry (LC/MS)

c. Coupled with tandem mass spectrometry (LC/MS/MS)

7.3.2.2. Gas chromatography (GC)

a. Coupled with ultraviolet spectrometry (GC/MS)

b. Coupled with electron capture detector (GC/ECD)

c. Coupled with nitrogen-phosphorus detector (GC/NPD)

7.3.2.3. Inductively coupled plasma (ICP)

a. Coupled with atomic emission spectrometry (ICP-AES)

b. Coupled with mass spectrometry (ICP-MS)

7.3.2.4. XRF spectrometry

7.3.2.5. Graphite furnace atomic absorption spectrophotometry (GFAA)

7.3.2.6. Cold vapor atomic absorption spectrophotometry (CVAA)

7.3.2.7. Ion chromatography (IC)

7.3.2.8. Immunoassay

7.3.2.9. Colorimetry (visible spectrophotometry)

7.3.3. Analytical Methods. Later sections in this chapter describe the analytical methods that use the instrumentation listed above to detect specific classes of MC.

7.4. Primary Explosives.

7.4.1. Primary explosives are those extremely sensitive explosives (or mixtures thereof) that are used in primers, detonators, and blasting caps. Heat, sparks, impact, or friction easily detonates them. Primary explosives typically are present only in small quantities in munitions due to their sensitivity. Table 7-1 lists examples of primary explosives and their typical uses.

Table 7-1: Primary Explosives and Typical Uses

| Primary Explosive | Typical Use | CAS Number[a] |
|---|---|---|
| Lead azide[b] | Initiator for HE | 13424-46-9 |
| Mercury fulminate[b] | Initiator for HE | 628-86-4 |
| Diazodinitrophenol | Priming compositions, commercial blasting caps | 4682-03-5 |
| Lead styphnate[b] | Priming compositions, ignition of lead azide | 15245-44-0 |
| Tetracene | Priming compositions, boosters | 92-24-0 |
| Potassium dinitrobenzofuroxane (KDNBF) | Priming compositions | Not available |
| Lead mononitroresorcinate | Priming compositions, electric detonators | 51317-24-9 |

a Chemical Abstracts Service registry number

[b] More common

7.4.2. Sampling based on release of primary explosives on testing or training ranges is not recommended because of the small amount present in any single munition (typically much smaller amount than the filler) and because the primary explosive is consumed if any part of the explosive train of a munition functions. This recommendation does not apply to primary explosives manufacturing facilities. Analytical methodology does not widely exist to detect primary explosives. For instance, analysis for lead measures the total lead and cannot be used to infer the presence or absence of lead-containing primary explosives due to the lack of specificity. Similarly, analysis for mercury cannot be used to infer the presence or absence of mercury fulminate.

7.4.3. Soil containing 2% or more by weight of any primary explosive or mixture of primary explosives presents an explosive hazard. Such mixtures are referred to as explosive soils as defined in DoD 6055.09, V7E4.4.1.

7.5. Secondary Explosives.

7.5.1. Secondary explosives are used as the main bursting charge or as the booster that sets off the main bursting charge. Secondary explosives are much less sensitive than primary explosives. They are less likely to detonate if struck or when exposed to friction or to electrical sparks. Secondary explosives also are used for the main fill in many munitions. Commonly used booster and secondary explosives are listed in Table 7-2.

Table 7-2: Secondary Explosives

| Explosives Compound | Abbreviation or Acronym | CAS Number |
|---|---|---|
| **Aliphatic Nitrate Esters** | | |
| 1,2,4-Butanetriol trinitrate | BTN | 6659-60-5 |
| Diethyleneglycol dinitrate | DEGN | 693-21-0 |
| Nitrocellulose[a] | NC | 9004-70-0 |
| Nitroglycerin[a] | NG | 55-63-0 |
| Nitrostarch | NS | 9056-38-6 |
| Pentaerythritol tetranitrate | PETN | 78-11-5 |
| Triethylene glycoldinitrate | TEGN | 111-22-8 |
| 1,1,1-Trimethylolethane trinitrate | TMETN | 3032-55-1 |
| **Nitramines** | | |
| Octahydro-1,3,5,7-tetranitro 1,3,5,7-tetrazocine | HMX | 2691-41-0 |
| Hexahydro-1,3,5 trinitro-1,3,5-triazine | RDX | 121-82-4 |
| Ethylenediamine dinitrate | EDDN | 20829-66-7 |
| Ethylenedinitramine | Haleite | 505-71-5 |
| Nitroguanidine[a] | NQ | 556-88-7 |
| 2,4,6-Trinitrophenylmethylnitramine | Tetryl | 479-45-8 |
| **Nitroaromatics** | | |
| Ammonium picrate | AP | 131-74-8 |
| 1,3-Diamino-2,4,6-trinitrobenzene | DATB | 1630-08-6 |
| 2,2’,4,4',6,6'-Hexanitroazobenzene | HNAB | 19159-68-3 |
| 1,3,5-Triamino-2,4,6-trinitrobenzene | TATB | 3058-38-6 |
| 2,4,6-Trinitrotoluene | TNT | 118-96-7 |
| **Other** | | |
| Ammonium nitrate | | 6484-52-2 |

Source: TM 9-1300-214 Military Explosives

a NC, NG, and NQ also are used as propellants. Additional information regarding NC, NG, and NQ is provided in Section 7.6.

7.5.2. Secondary explosives are the main ingredients in composition explosive formulations. Composition explosives consist of one or more explosive compounds mixed with other ingredients to produce an explosive with more suitable characteristics for a particular application. Some typical examples of composition explosives are listed in Table 7-3. Exact compositions vary; they are documented in TM 9-1300-214.

Table 7-3: Composition Explosive Makeup

| Composition Explosive | Explosive Compounds | Other Ingredients [a] |
|---|---|---|
| **Binary Mixtures** | | |
| Amatols | Ammonium nitrate and TNT | |
| Composition A (A, A2, A3, A4, A5, A6) | RDX | Beeswax, synthetic wax, desensitizing wax, stearic acid, or polyethylene |
| Composition B (Cyclotol, B, B2, B3) | RDX and TNT | Wax, calcium silicate |
| Composition C (C, C2, C3, C4) | RDX, explosive plasticizer (C2 contained nitrotoluenes, dinitrotoluenes, TNT, NC, dimethylformamide; C3 contained nitrotoluenes, dinitrotoluenes, TNT, tetryl, and NC) | Nonexplosive oily plasticizer (included lecithin) or polyisobutylene; may also contain lead chromate and lamp black |
| Composition CH6 | RDX | Calcium stearate, graphite, polyisobutylene |
| Ednatols | TNT and haleite (ethylene dinitramine) | |
| Octols | HMX and TNT | |
| Pentolite | PETN and TNT | |
| Picratol | AP and TNT | |
| Tetrytol | Tetryl and TNT | |
| Tritonal | TNT | Flaked aluminum |
| **Tertiary Mixtures** | | |
| Amatex 20 | RDX, TNT, ammonium nitrate | |
| Ammonal | Ammonium nitrate and TNT, DNT, or RDX | Powdered aluminum |
| High Blast Explosives (HBX-1, HBX-3, HBX-6) | RDX, TNT [b], nitrocellulose | Calcium chloride, calcium silicate, aluminum, wax, and lecithin |
| HTA-3 | HMX, TNT | Aluminum and calcium silicate |
| Minol | TNT and ammonium nitrate | Aluminum |
| Torpex | RDX and TNT | Aluminum powder and wax |
| **Quaternary Mixtures** | | |
| Depth Bomb Explosive (DBX) | TNT, RDX, ammonium nitrate | Aluminum |

Source: TM 9-1300-214

a Varies by type, may contain any or all other ingredients listed.

b HBX-6 does not contain TNT.

7.5.3. Many secondary explosives are composed of organic compounds that can be transformed (degraded) in the environment. Transformation of explosive compounds may occur via abiotic processes (e.g., photolysis) or biotic transformation (e.g., aerobic or anaerobic biodegradation). Most of the research in the domain of energetics compounds transformation has focused on TNT, RDX, HMX, and DNTs; limited data are also available for tetryl, NG, picric acid, and PETN. Information regarding transformation of these secondary explosives compounds, as well as other fate and transport properties (e.g., sorption, dilution, advection, dispersion, diffusion), is provided in Engineer Research and Development Center (ERDC) / Cold Regions Research and Engineering Laboratory (CRREL) TR-06-18, Conceptual Model for the Transport of Energetic Residues from Surface Soil to Groundwater by Range Activities (2006) and in other publications listed in Appendix A of this manual. Table 7-4 lists breakdown products as well as co-contaminants for common secondary explosives.

Table 7-4: Breakdown Products and Co-Contaminants of Common Secondary Explosives

| Compound | Description[a] | Abbreviation | CAS Number |
|---|---|---|---|
| Octahydro-1, 3, 5, 7-tetranitro-1,3,5,7-tetrazocine | Nitramine explosive; also RDX co-contaminant | HMX | 2691-41-0 |
| Hexahydro-1,3,5-trinitro-1,3,5-triazine | Nitramine explosive; also HMX co-contaminant | RDX | 121-82-4 |
| 1,3,5-Trinitrobenzene | TNT co-contaminant and breakdown product | 1,3,5-TNB | 99-35-4 |
| 1,3-Dinitrobenzene | DNT breakdown product and TNT co-contaminant | 1,3-DNB | 99-65-0 |
| Nitrobenzene | DNT co-contaminant | NB | 98-95-3 |
| 4-Amino-2,6-dinitrotoluene | TNT breakdown product | 4-Am-DNT | 1946-51-0 |
| 2-Amino-4,6-dinitrotoluene | TNT breakdown product | 2-Am-DNT | 355-72-78-2 |
| 2,4-Diamino-6-nitrotoluene | TNT breakdown product | 2,4-DANT | 6629-29-4 |
| 2,6-Diamino-4-nitrotoluene | TNT breakdown product | 2,6-DANT | 59229-75-3 |
| 2,4-Dinitrotoluene | Nitroaromatic explosive/propellant; also TNT co-contaminant | 2,4-DNT | 121-14-2 |
| 2,6-Dinitrotoluene | Nitroaromatic explosive/propellant; also TNT co-contaminant | 2,6-DNT | 606-20-2 |
| 2-Nitrotoluene (o-Nitrotoluene) | DNT co-contaminant | 2-NT | 88-72-2 |
| 3-Nitrotoluene (m-Nitrotoluene) | DNT co-contaminant | 3-NT | 99-08-1 |
| 4-Nitrotoluene (p-Nitrotoluene) | DNT co-contaminant | 4-NT | 99-99-0 |
| Hexahydro-1-nitroso-3,5-dinitro-1,3,5-triazine | RDX breakdown product | MNX | 5755-27-1 |
| Hexahydro-1,3-dinitroso-5-nitro-1,3,5-triazine | RDX breakdown product | DNX | 80251-29-2 |
| Hexahydro-1,3,5-trinitroso-1,3,5-triazine | RDX breakdown product | TNX | 13980-04-6 |
| 3,5-Dinitroaniline | TNB breakdown product | 3,5-DNA | 618-87-1 |

a Information gathered from TM 9-1300-214; Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles for 2,4- and 2,6-Dinitrotoluene and for 2,4,6-Trinitrotoluene (located at http://www.atsdr.cdc.gov/toxprofiles/index.asp) and the Hazardous Substances Data Bank (located at http://toxnet.nlm.nih.gov/).

7.5.4. Several analytical methods are used to analyze for nitroaromatic/nitramine secondary explosives and their breakdown products. Currently available methods are provided in Table 7-5. A version of SW8330 typically is used unless significant interferences are anticipated. Some laboratories are unable to perform quantitative second column confirmation for explosives per DoD Quality Systems Management (QSM) / SW8000C (i.e., five-point calibrations must be performed for each target analyte for the primary and confirmatory columns and quantitative results for each column must be reported). This requirement should not be waived for MR projects. Based upon review of chemical-specific DQOs through the TPP process, exceptions may be considered for the following co-eluting pairs: 2-AM-DNT/4-AM-DNT, 2-NT/4-NT, and 2,4-DNT/2,6-DNT. SW8095 may be recommended if lower reporting limits are required, but it is not widely available commercially. SW8321 typically is used for complex matrices where there is concern regarding confirmation of positive results. Laboratories with coelution problems also may use it for SW8330; however, routine use of LC/MS confirmation to compensate for the laboratory's failure to properly execute SW8330 should not incur additional cost to the government. For all aqueous samples, sample preparation should be performed IAW SW3535A solid phase extraction (SPE) rather than by the SW8330 salting out procedure unless a reasonable technical rationale (i.e., SPE disk clogging) is documented. Analytical method selection should be based on the DQOs determined during TPP conducted for the project. If previous data exist, it may be appropriate to use the same analytical methodology; however, meeting current DQOs is the more relevant requirement.

Table 7-5: Fixed Laboratory Tests for Nitrogen-Based Explosives, Co-Contaminants, and Breakdown Products

| Method No. | Title | Advantages[a] | Disadvantages[a] |
|---|---|---|---|
| SW8330A | Nitroaromatics and Nitramines by High Performance Liquid Chromatography (HPLC) | Broad commercial availability; two column confirmation | LC is laboratory-dependent; many laboratories have second column resolution problems |
| SW8330B[b,c] | Nitroaromatics, Nitramines, and Nitrate Esters by High Performance Liquid Chromatography (HPLC) | | |
| SW8332[d] | Nitroglycerine by HPLC | Broad commercial availability | Chromatography is laboratory dependent |
| SW8095 | Explosives by Gas Chromatography (GC) | Low limit of quantitation (LOQ) | Limited commercial availability |
| Modified SW8321A[e] | Explosives by HPLC/Thermospray/Mass Spectrometry (HPLC/TS/MS) or Ultraviolet detection | Low LOQ; MS confirmation; commercial availability increasing; additional compounds available | No published method; certification based on laboratory SOPs; MS is a selected ion monitoring (SIM) scan, not full spectral confirmation; data review more difficult |
| USAPHC Method[f] | GC; Isoamyl acetate extraction | Low LOQ; two column confirmation | Limited commercial availability; certification based on laboratory SOPs |

Note: USAPHC = United States Army Public Health Command

a Advantages and disadvantages are based strictly on analytical technique, not sample preparation technique.

b This method includes additional ultraviolet (UV) wavelengths to allow for detection of NG and PETN.

c Method states "ring puck mill or equivalent mechanical grinder" for soil analysis. The DoD QSM requires the laboratory to demonstrate that the grinding procedure is capable of reducing the particle size to less than 75 micrometers (μm) by passing representative portions of ground sample through a 200 mesh sieve. To date, during program audits, EM CX has not recognized the equivalency of a ball mill due to concerns regarding potential analyte loss and effectiveness of propellant grain processing.

d Since the publication of method SW8330B, this method is rarely referenced.

e This method typically is cited for HPLC/MS of explosives. However, no published version includes explosives. An effort is underway to update SW8321 that would address explosives; however, no schedule is available as to the release of this update.

f Hable et al., 1991

7.5.5. Field tests for nitrogen-based explosives are shown in Table 7-6. Fate and transport properties (e.g., advection, adsorption, transformation, and volatilization) of the analytes should be considered prior to the use of field tests, particularly if the use of TNT or RDX as an indicator compound is intended. It is anticipated that for a range that has been out of use for a substantial period of time, most, if not all TNT, would have broken down due to photodegradation and biodegradation. RDX is less likely to have broken down but may not be an appropriate indicator compound at older sites, as RDX has been widely used only post-World War II (WWII).

Table 7-6: Field Tests for Nitrogen-Based Explosives

| Method No. | Title |
|---|---|
| SW4050 | TNT Explosives in Soil by Immunoassay |
| SW4051 | RDX in Soil by Immunoassay |
| SW8515 | Colorimetric Screening Method for TNT in Soil |
| SW8510 | Colorimetric Screening Procedure for RDX and HMX in Soil |
| N/A | DropEx Plus (Explosives Detection Field Test Kit) |
| N/A | Expray™ (Plexus Scientific) |

Note: N/A = No method number

7.5.5.1. Immunoassays. Immunoassays have been developed for TNT and RDX in soil. Methods SW4050 for TNT and SW4051 for RDX may be used for screening soil to determine when TNT and RDX are present at concentrations above 0.5 milligrams per kilogram. Commercially available tests have little cross-reactivity with other nitroaromatic/nitramine explosives. Therefore, they may not be appropriate for use at older sites where these parent compounds may have been degraded or transformed.

7.5.5.2. Quantitative Colorimetric Analysis. Methods SW8510 (for RDX and HMX in soil) and SW8515 (for TNT in soil) are colorimetric analyte-specific tests that can be performed using commercially available kits. The methods are performed using an extract of a soil sample. The sample extract is treated with color-change reagents and is analyzed in a portable spectrophotometer. These methods may be used to analyze for other analytes but require documentation of method modifications used to acquire the other analytes. For additional information regarding field analysis of analytes other than TNT, RDX, and HMX see Jenkins et al., 1995.

7.5.5.3. Qualitative Colorimetric Analysis. Two colorimetric test kits for general analyte classes are available (EXPRAY™ in aerosol form and DropEx Plus in liquid form). These products may be used in the field or in the laboratory to determine whether nitroaromatic explosives, nitramine and nitrate ester explosives, or inorganic nitrates are present. They typically are used qualitatively, although they can be used semi-quantitatively with sufficient expertise, as documented in SW8330B and in ERDC/CRREL TN-05-2, Pre-Screening for Explosives Residues in Soil Prior to HPLC Analysis Utilizing Expray™ (http://www.crrel.usace.army.mil/library/technicalnotes/TN05-2.pdf). The EXPRAY™ kit is shipped from the manufacturer as a DOT Hazardous Material, so logistics related to appropriate shipment considerations must be evaluated if the kit is used.

7.5.6. Analysis of AP, picric acid, less common TNT breakdown products (e.g., diaminonitrotoluenes [DANTs]), and RDX breakdown products (typically MNX, DNX, and TNX) may be required but are not part of current methods published by the USEPA. These analytes can be analyzed with published or modified SW8330 methods (nitroaromatics and nitramines by HPLC), SW8330B (PETN), and SW8095 (explosives by GC), SW8321A (solvent-extractable nonvolatile compounds by HPLC); however, AP typically is reported based on the analysis of picric acid. If analytes that are not part of methods published by the USEPA are included in the project, the PDT and stakeholders must accept any proposed analytical and documentation must be provided in the project UFP-QAPP regarding any method modifications or unpublished methods.

7.5.7. Although NC, NG, and NQ are secondary explosives, they are also commonly used as propellants. A detailed discussion regarding laboratory analysis of these compounds is provided in Section 7.6.9.

7.6. Propellants.

7.6.1. Propellants are designed to provide energy to deliver a munition to its target. The key difference between explosives and propellants is their reaction rate. Explosives react rapidly, creating a high-pressure shock wave, and are designed to break apart a munitions casing and cause injury. Propellants react at a slower rate, creating a sustained lower pressure used to propel a munition.

7.6.2. Propellants are found in cartridge cases (small arms, medium caliber munitions, some artillery), external to the projectile (mortars, some artillery), in rocket motors, and in explosive charges in some munitions.

7.6.3. Propellants are divided into four classes: single-base, double-base, triple-base, and composite. Division of the propellants into these classes is on the basis of their composition and not their use. The following publications prepared by the U.S. Army Defense Ammunition Center (DAC) provide information on propellant identification and management:

a. DAC Propellant Management Guide (https://www.us.army.mil/suite/doc/9025261)

b. DAC Propellant Identification Manual (https://www.us.army.mil/suite/page/257916)

(The Web sites referenced above are hosted on Army Knowledge Online [AKO]; a Common Access Card [CAC] or AKO account is required to download the documents from these locations. Contractors should coordinate with their government points of contact to obtain the referenced documents.)

7.6.4. Table 7-7 lists the composition and typical use of each propellant class.

Table 7-7: Composition and Typical Use of Propellants

| Propellant Class | Composition | Typical Use |
|---|---|---|
| Single-base | Primarily NC. In addition to a stabilizer, may also contain inorganic nitrates, nitrocompounds, metallic salts, metals, carbohydrates, or dyes. | Small arms, mortar shells, artillery shells up to 280 mm, as propelling charge in naval guns |
| Double-base | Primarily NC and NG; stabilizer and additives similar to single-base | Cannons, small arms, mortars, artillery, rockets, jet propulsion units |
| Triple-base | NQ (major ingredient) as well as NC and NG; stabilizer and additives similar to single-base | Gun propellants for mortar and artillery shells |
| Composite | Fuel (e.g., metallic aluminum), binder (normally an organic polymer such as synthetic rubber, which is also a fuel), and an inorganic oxidizing agent (e.g., ammonium perchlorate) | Rocket assemblies and jet propulsion units |

Source: TM 9-1300-214 Military Explosives, 1984

7.6.5. Formulations of propellants vary even within named propellant types (e.g., M1, a single-base propellant, has three compositions). Substitutes and additives used in propellant compositions include the following:

a. Diphyenylamine – stabilizer for single-base propellant

b. Ethyl centralite (EC) (Centralite I) – used for double- and triple-base propellants, which use NG as the gelatinizing agent for the NC

c. Methyl centralite (MC) (Centralite II) – less commonly used in place of EC

7.6.6. The majority of the material comprising a propellant is expected to be expended upon use. For an MC investigation, the focus is on the primary compounds comprising the propellant. The lesser compounds (e.g., stabilizer, additives) are found in very small quantities in the propellant composition, and some do not have standard commercially available analytical methods. Also, some of the lesser compounds are used for other purposes (e.g., phthalates), so their presence is not necessarily indicative of DoD use.

7.6.7. Perchlorate. Perchlorate (CAS Number 14797-73-0) is the anion of perchloric acid and is found in composite propellants. Perchlorate is of special concern due to its mobility and toxicity. Two salts of primary concern are ammonium perchlorate (CAS Number 7790-98-9, $NH_4ClO_4$) and potassium perchlorate (CAS Number 7778-74-7, $KClO_4$). Current guidance and locations from which the guidance may be obtained on the Internet include the following:

a. DoD Perchlorate Release Management Policy, April 22, 2009
http://www.denix.osd.mil/cmrmd/upload/dod_perchlorate_policy_04_20_09.pdf

b. USEPA Revised Assessment Guidance for Perchlorate, January 8, 2009
http://www.denix.osd.mil/cmrmd/upload/EPA-perchlorate_memo_01-08-09.pdf

c. USEPA Interim Drinking Water Health Advisory, January 8, 2009
http://www.denix.osd.mil/cmrmd/upload/healthadvisory_perchlorate_interim.pdf

d. DoD Perchlorate Handbook, August 2007
http://www.denix.osd.mil/edqw/Perchlorate.cfm

e. Federal Facilities Restoration and Reuse Office Technical Fact Sheet -Perchlorate
http://www.epa.gov/fedfac/pdf/technical_fact_sheet_perchlorate.pdf

7.6.7.1. The ITRC Perchlorate Team provides additional information, including Perchlorate: Overview of Issues, Status, and Remedial Options (2005) and Remediation Technologies for Perchlorate Contamination in Water and Soil (2008) available at (http://www.itrcweb.org/teampublic_Perchlorate.asp) and http://www.itrcweb.org/guidancedocument.asp?TID=32.

7.6.7.2. The DoD Perchlorate Handbook (2007) provides assistance for development of a CSM for areas known or suspected to have had a perchlorate release.

7.6.7.3. DoD munitions, munition components, and training devices that may have contained perchlorate, include the following (DoD Perchlorate Handbook, 2007):

a. Solid fuel rockets

b. Mines

c. Torpedo warheads

d. Smoke-generating compounds

e. Signal flares

f. Parachute flares

g. Star rounds for pistols (illumination rounds)

h. Thermite-type incendiaries

i. Tracer rounds

j. Incendiary bombs

k. Fuzes

l. Jet-assisted takeoff devices

m. Training simulators

7.6.7.4. For an MC investigation, it is important to identify potential naturally occurring background sources and non-DoD sources of perchlorate. Some known non-DoD sources of perchlorate include the following (DoD Perchlorate Handbook, 2007):

a. Commercial blasting (for construction) with perchlorate-containing explosives

b. Use of perchloric acid in manufacturing processes

c. Perchlorate-containing fertilizer

d. Perchlorate-containing sodium chlorate used as an herbicide

e. Commercial manufacture of perchlorate salts of perchlorate-containing items (e.g., pyrotechnics, flares)

7.6.7.5. If perchlorate is detected at fairly low concentrations in groundwater (e.g., < 20 micrograms per liter [µg/L]), then forensic analysis to distinguish between synthetic and natural sources of perchlorate should be considered. Natural sources of perchlorate include fertilizers imported from Chile as well as natural sources indigenous to the United States. Chlorine and oxygen isotopic analyses of perchlorate provide the primary direct approach whereby different sources of perchlorate can be distinguished from each other. These techniques measure the relative abundances of the stable isotopes of chlorine ($^{37}Cl$ and $^{35}Cl$) and oxygen ($^{18}O$, $^{17}O$, and $^{16}O$) in perchlorate using isotope-ratio mass spectrometry. In addition, the relative abundance of the radioactive chlorine isotope $^{36}Cl$ is measured using accelerator mass spectrometry. These measurements provide four independent quantities (isotope abundance ratios) for distinguishing perchlorate sources and potential transformations in the environment. Guidance for performing perchlorate forensics analyses is provided in Validation of Chlorine and Oxygen Isotope Ratio Analysis To Differentiate Between Perchlorate Sources and to Document Perchlorate Biodegradation, ESTCP Project ER-200509 (Hatzinger et al., 2011).

7.6.7.6. Because of the high solubility and low sorption characteristics of perchlorate, the primary media of concern for perchlorate are typically groundwater and surface water. However, soil sampling may be considered at sites with the following conditions (DoD Perchlorate Handbook, 2007):

a. Large quantities of perchlorate were used, disposed of, or burned at the site.

b. A perchlorate source is likely to be present, and the soils and vadose zone matrix have an affinity to retain interstitial water.

c. The climatic conditions result in high evapotranspiration rates.

d. Perchlorate-laden groundwater or surface water can discharge to the ground surface and are subject to high evaporation rates.

e. A perchlorate source is ongoing because of on-site testing, use, or disposal.

f. Groundwater contamination is elevated and suggests the presence of ongoing soil contamination emanating from an unknown source area.

7.6.8. <u>Black Powder</u>. Black powder was used as a propellant prior to the development of smokeless propellants. It was used mostly prior to WWII in munitions and pyrotechnics. Black powder typically contains mostly potassium or sodium nitrate (70% to 75% by weight), charcoal (14% to 16% by weight), and sulfur (10% to 16% by weight). When the composition is ignited, the sulfur and charcoal act as fuels, while the potassium nitrate or sodium nitrate works as an oxidizer. The components of black powder typically are not analyzed during an MC investigation. This should be addressed during TPP with stakeholders. The rationale for not sampling is as follows: the only potential analytes would be ions (e.g., potassium, sodium, nitrate), which would be difficult to attribute to DoD contamination, as they commonly are found as essential nutrients (potassium and sodium) and in widespread use as fertilizer (nitrate)  In addition, the toxicity of these ions is very low.

7.6.9. Fixed Laboratory Tests for Propellants.

7.6.9.1. NC. There is no widely used analytical method for NC, which is relatively nontoxic. U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) / U.S. Army Environmental Hygiene Agency (USAEHA) methods LF03 and UF03, or variants based on them, still remain in use in some labs. However, their use is discouraged due to the documented issues with the methods, which include lack of specificity relative to other sources of nitrate/nitrite. These methods are indirect measurements. For soil samples, the NC is extracted with acetone, the nitrate/nitrate ions are separated from the extract, the nitrogroups on the NC are hydrolyzed to nitrite, and nitrite is measured colorimetrically. For accurate NC concentrations to be determined, the percent nitrogen in NC must be known (which generally is not realistic in most environmental samples). Data can be compromised by any of the processes being incomplete (i.e., separation of nitrate/nitrite ions from the extract [high bias], extraction of NC from soil [low bias], and hydrolysis of NC [low bias]). For water, the NC is filtered and the filter is washed to remove the nitrate/nitrite ions prior to a similar process as above for the soils. There is a new IC method that has been published in a journal article; however, it has not been recognized by the USEPA or any of the national method publication bodies at this time (Macmillan et al., 2008)

7.6.9.2. NG. NG may be measured using the following methods:

a. USEPA 8332 – NG by HPLC

b. LC/MS – Modified USEPA 8321A Solvent-Extractable Non-volatile Compounds by HPLC/Thermospray/MS or UV Detection

c. USEPA 8330B, which includes NG

7.6.9.3. NQ. NQ may be measured using the following methods:

a. USATHAMA/USAEHA HPLC methods LW30 (soil) and UW29 (water)

b. Modified 8330 or 8321A (not published in methods)

7.6.9.4. Perchlorate. Perchlorate is primarily measured using fixed laboratory tests; however, field laboratory methods are also in development. Filtration using a 0.2 μm filter is required by the DoD Perchlorate Handbook for preservation of perchlorate.

7.6.9.4.1. All fixed laboratory tests for perchlorate are based on ion chromatography or liquid chromatography. The DoD Perchlorate Handbook requires that detections of perchlorate above reporting levels be confirmed with mass spectrum confirmation. Fixed laboratory tests for perchlorate are shown in Table 7-8.

Table 7-8: Fixed Laboratory Tests for Perchlorate

| Method No. | Title | DoD Perchlorate Handbook Status |
|---|---|---|
| USEPA 331.0 | Determination of Perchlorate in Drinking Water by Liquid Chromatography Electrospray Ionization Mass Spectrometry | Recommended for drinking water |
| USEPA 332.0 | Determination of Perchlorate in Drinking Water by Ion Chromatography with Suppressed Conductivity and Electrospray Ionization Mass Spectrometry | Recommended for drinking water |
| SW6850 | Perchlorate in Water, Soils and Solid Wastes Using High Performance Liquid Chromatography / Electrospray Ionization / Mass Spectrometry | Recommended for drinking water, groundwater, soil, and wastewater |
| SW6860 | Perchlorate In Water, Soils And Solid Wastes Using Ion Chromatography / Electrospray Ionization/Mass Spectrometry | Recommended for drinking water, groundwater, soil, and wastewater |
| USEPA 314.0 | Determination of Perchlorate in Drinking Water by Ion Chromatography | Not recommended Only allowed for existing NPDES permits. |
| USEPA 314.1 | Determination of Perchlorate in Drinking Water Using Inline Column Concentration / Matrix Elimination Ion Chromatography with Suppressed Conductivity Detection | Not recommended All results above the method reporting limit must be confirmed using MS. |
| Draft SW9058 | Determination of Perchlorate Using Ion Chromatography with Chemical Suppression Conductivity Detection | Not recommended All results above the method reporting limit must be confirmed using MS. |

7.6.9.4.2. Field tests based on an ion-selective electrode (ISE), colorimetry, capillary electrophoresis, and ion mobility/MS exist for perchlorate, but they have not been widely used at this time. The ISE method is documented in Perchlorate Screening Study: Low Concentration Method for the Determination of Perchlorate in Aqueous Samples Using Ion Selective Electrodes: Letter Report of Findings for the Method Development Studies, Interference Studies, and Split Sample Studies, including Standard Operating Procedure, available at http://www.clu-in.org/programs/21m2/letter_of_findings.pdf. The colorimetry test is documented in CRREL TR 04-8, Field Screening Method for Perchlorate in Water and Soil, available at http://www.crrel.usace.army.mil/library/technicalreports/TR04-8.pdf.

7.7. Metals.

7.7.1. Metals are found in nearly all military munitions and are used in munitions casings, bullets, projectile cases, projectiles, bomb bodies, and fillers. Certain munitions contain only metals (i.e., incendiaries). Table 7-9 lists metals that occur in munitions, their regulatory status, and their common oxidation states.

Table 7-9: Metals Occurrence in Munitions, Regulatory Status, and Common Oxidation States

| Metal | Occurrence in Munitions | CERCLA Hazardous Substance in Elemental Form?[a,b] | Are Compounds Hazardous Substances?[c] | Common Oxidation States |
|---|---|---|---|---|
| **More Commonly Occurring MC Metals** | | | | |
| Aluminum (Al) | Incendiaries, composition explosives, propellants, pyrotechnics (powdered Al), and rocket cases (alloys) | No | Only certain compounds | Al(0); Al(III) |
| Antimony (Sb) | Alloys with Pb in small arms bullets (99% Pb, 1% Sb) and in pyrotechnics | Yes | Yes | Sb(0); Sb(III); Sb(V) |
| Copper (Cu) | Cartridge cases (brass), bullet jackets (e.g., gilding metal), pyrotechnics, and bronze gun barrels | Yes | Yes | Cu(0); Cu(I); Cu(II) |
| Iron (Fe) | Present as steel in cases and projectiles, incendiaries, and pyrotechnics | No | No | Fe(0); Fe(II); Fe(III) |
| Lead (Pb) | Small arms bullets, primary explosives, primer compositions | Yes | Yes | Pb(0); Pb(II); Pb(IV) |
| Magnesium (Mg) | Incendiaries, pyrotechnics (photoflash), tracers, and armor piercing bullets | No | No | Mg(0); Mg(II) |
| Zinc (Zn) | Cartridge cases (brass) bullet jackets (e.g., gilding metal), HC smoke-filled munitions, and pyrotechnics | Yes | Yes | Zn(0); Zn(II) |
| **Less Commonly Occurring MC Metals** | | | | |
| Arsenic (As) | Present in alloys with Pb in shotgun pellets (96.4% Pb, 3% Sb, 0.6% As), in yellow smoke, arsenical CWM, and in vomiting agents | Yes | Yes | As(0); As(III); As(V); occurs as anionic species in solution (e.g. $HAsO_4^{2-}$) |
| Barium (Ba) | Present as barium nitrate in some pyrotechnics, detonators, fuzes, primers, composition explosives | No | Only barium cyanide | Ba(II) |
| Boron (B) | Blasting caps, igniters, pyrotechnics | No | No | B(III) |
| Cadmium (Cd) | Pyrotechnics | Yes | Yes | Cd(0); Cd(II) |
| Calcium (Ca) | Smoke formulations | No | Only certain compounds | Ca(0); Ca(II) |
| Chromium (Cr) | Armor piercing bullets, pyrotechnics, present in some steel alloys | Yes | Yes | Cr(0); Cr(II); Cr(III); Cr(VI) |
| Cobalt (Co) | Pyrotechnics, present in some steel alloys | No | Yes | Co(0); Co(II); Co(III) |
| Lithium (Li) | Pyrotechnics | No | Only lithium chromate | Li(I) |

| Metal | Occurrence in Munitions | CERCLA Hazardous Substance in Elemental Form?[a,b] | Are Compounds Hazardous Substances?[c] | Common Oxidation States |
|---|---|---|---|---|
| Manganese (Mn) | Pyrotechnics, delay powders, present in some steel alloys | No | Yes | Mn(0); Mn(II); Mn(III), Mn(IV); Mn (VII) |
| Mercury (Hg) | Some primer mixtures (mercury fulminate; used prior to WWII) | Yes | Yes | Hg(0); Hg(II) |
| Molybdenum (Mo) | Armor piercing bullets, igniter compositions, propellant compositions, alloying agent in steel | No | No | Mo(VI) |
| Nickel (Ni) | Pyrotechnics, delay powders, present in some steel alloys | Yes | Yes | Ni(0); Ni(II); Ni(III) |
| Potassium (K) | Potassium nitrate in black powder (used in variety of munitions), potassium perchlorate in pyrotechnics and propellants | No | Only certain compounds | K(0); K(I) |
| Selenium (Se) | Delay and igniter compounds, pyrotechnics, additive in stainless steels | Yes | Yes | Se(0); Se(IV); Se(VI) |
| Silver (Ag) | Present in igniter compounds and pyrotechnics | Yes | Yes | Ag(I) |
| Strontium (Sr) | Present in some pyrotechnics (e.g., tracer compositions, flares) | No | Only strontium chromate | Sr(II) |
| Tin (Sn) | Smokeless propellants as antifouling agent, smoke (tin tetrachloride) | No | No | Sn(0); Sn(II); Sn(IV) |
| Titanium (Ti) | Pyrotechnics, M36 bomb clusters, smokes (in FM smoke as titanium tetrachloride) | No | Only titanium tetrachloride | Ti(0); Ti(II); Ti(III); Ti(IV) |
| Tungsten (W) | Armor piercing bullets, delay compositions, incendiary compositions for small arms, "green small arms" (does not apply to FUDS) | No | No | W(0); W(VI) |
| Uranium (U) | Some armor penetrators contain depleted uranium; incendiaries | No | No | U(0); U(IV); U(VI) |
| Vanadium (V) | Pyrotechnics, present in some steel alloys | No | Only certain compounds | V(0); V(II); V(III); V(IV); V(V) |
| Zirconium (Zr) | Armor piercing incendiary ammunition, incendiary cluster bombs, shaped-charges, pyrotechnics, alloying agent in steel | No | Only certain compounds | Zr(IV) |

a Elemental metals (other than Hg) are not hazardous substances unless their particle size diameter is less than or equal to 100 μm (0.004 inches).

b Some metals, such as U, V, W, and Zr, may be hazardous substances when present as radioactive isotopes.

c See 40 CFR 302.4 for a complete list of hazardous substance compounds.

7.7.2. The fate and transport of metals MC is highly complex and is governed by several major reaction types, including dissolution-precipitation as a function of pH and redox environment and sorption-desorption reactions as a function of soil composition, extent of soil saturation, and soil organic content. Fate and transport of lead has been studied extensively in relation to small arms ranges (SARs). ERDC/CRREL TR-07-11 (Environmental Assessment of Lead at Camp Edwards, Massachusetts, Small Arms Ranges, 2007) has a detailed discussion regarding the chemistry of lead and processes that govern its fate and transport. ERDC/EL TR-07-06 (Treatment and Management of Closed or Inactive Small Arms Firing Ranges, 2007) also provides a comprehensive discussion of the geochemistry of metals at SARs, including speciation effects and fate and transport considerations. An extensive literature review with an in-depth discussion of the geochemistry of lead is provided by Clausen et al. (2011). Through the Green Ammunition Program at the U.S. Army Armament Research, Development, and Engineering Center, the U.S. Army developed a 5.56 mm projectile with a tungsten core to replace the lead core in the mid-1990s as an environmental benign replacement for the lead/antimony projectile. Tungsten metal was selected as a lead substitute because it was thought to be insoluble in water and nontoxic. Use of the tungsten rounds for training started in 1999 but was halted in early 2003 due to flight instability issues. Recent studies suggest that the material used in the Army’s tungsten projectiles dissolved in water and is mobile under some field conditions. As a result, ERDC conducted a study assessing the fate and transport properties of tungsten (ERDC TR-07-5, Fate and Transport of Tungsten at Camp Edwards Small Arms Ranges, 2007). Fate and transport information for the other MC metals may be gathered from USEPA databases and technical reports.

7.7.3. Metals analyses should be based on a limited list if the type(s) of ordnance are known or can be reasonably assumed. If the types of metals potentially present are not known, it is recommended to analyze for the Target Analyte List metals with the exception of beryllium, sodium, and thallium (as no known munitions contain these metals) or another relevant long list for metals analyses (e.g., a state-specific list). Depending upon munitions used on the site, tungsten, uranium, zirconium, titanium, and strontium also may be potential metals of concern. If metals are analyzed, the PDT and stakeholders should discuss establishing background conditions during TPP. For additional discussion of background considerations, see Chapter 8.

7.7.3.1. Field Tests. There are two published field tests available for metals: SW4500, Mercury in Soil by Immunoassay and SW6200, Field Portable X-Ray Fluorescence (XRF) Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment. SW6200 is appropriate for many but not all of the metals of interest. The method may be appropriate for iron, lead, copper, zinc, manganese, chromium, antimony, arsenic, mercury, barium, and strontium. Other field tests may be used on MR projects, if appropriate, but their use must be approved by the EM CX. Proper logistic planning must be in place if XRF is used. The low-level radioactive source does require appropriate shipping considerations and coordination if brought onto military installations.

7.7.3.2. Fixed Laboratory Tests. There are several published methods for metals other than mercury. Currently available tests for metals are shown in Table 7-10. Determination of the appropriate method should depend upon the established DQOs. For soil analysis, SW6010C is typically appropriate, although it may require the use of “ICP trace,” which is a newer version of equipment that can be used for SW6010C to provide a lower LOQ.  For lower reporting limits, SW6020A or SW7010 may be required.

Table 7-10:  Fixed Laboratory Tests for Metals

| Method Number | Title |
|---|---|
| SW6010C | Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) |
| SW6020A | Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) |
| SW7010 | Graphite Furnace Atomic Absorption (GFAA) Spectrophotometry |
| SW7470A/<br>SW7471B | Mercury by Cold Vapor Atomic Absorption (CVAA) |

7.7.3.3.   Small Arms–Specific Considerations.  One key aspect to characterizing metals in soils at a SAR is reaching consensus on whether to sieve the soil samples prior to analysis.  One of the primary reasons to sieve is to remove bullet fragments (if bullet fragments are sieved, they should be weighed by the laboratory).  Retaining bullet fragments would yield a higher concentration of lead; however, the lead in the fragments would not be readily available to receptors.  Also, lead fragments in analytical soil samples are likely to greatly increase variability in analytical results.  This subject is recommended for discussion at project TPP sessions.  If additional sample preparation is planned, it should be described thoroughly in the appropriate project planning documents.  This issue also will be very important if remediation is planned; a remediation contractor may need additional information on the mass of bullet fragments.

7.7.3.4.   Analytical Modifications for Tungsten.  Because the geochemistry of tungsten differs from most trace metals, analytical modifications are required to successfully analyze for tungsten.  Tungsten is not efficiently extracted from soil matrices using standard acid digestion procedures.  Addition of phosphoric acid to the sample digestion process improves extraction of tungsten.  Aqueous samples for tungsten analysis should be collected in plastic containers and should not be preserved with nitric acid (Bednar et al., 2010).

7.7.4.   Depleted Uranium (DU).  DU is a byproduct of the process used to enrich natural uranium for use in nuclear reactors and in nuclear weapons.  Natural uranium occurs as three isotopes with the following abundances (by weight):  99.28% U-238, 0.71% U-235, and 0.0058% U-234.  U-232, U-233, and U-236 are created from man-made processes.  The natural uranium enrichment process concentrates both the U-235 and U-234 isotopes, resulting in a byproduct depleted in both U-235 and U-234.  Because of the shorter half-life of U-235 and U-234 compared to U-238, the radioactivity associated with DU is approximately 40% less than that of natural uranium (Depleted Uranium Technical Brief, USEPA, 2006).  Because DU metal is 1.7 times more dense than lead, it is valuable for industrial and military uses.  DU has been used in military munitions in several ways:  as a kinetic energy penetrator to defeat armored targets, as ballast in the M101 spotting round, and in minute quantities as a catalyst in epoxy.  Epoxy that contains trace amounts of DU is used only in the M86 Pursuit Deterrent Munitions and the Area Denial Artillery Munitions.  DU also has other military applications, such as use in protective armor for tanks.  The armed forces have tested or used military munitions that contain a DU penetrator at a relatively small number of ranges.  The Nuclear Regulatory Commission licenses these ranges, including former ranges.  Additional information regarding the use of DU in military munitions is provided in the Final Army RI/FS Guidance (AEC, 2009) and in Properties, Use, and Health Effects of Depleted Uranium (DU): A General Overview (Bleise et al., 2003).

7.7.4.1. Field Tests. Uranium and DU can be detected by measuring emitted radiation, including alpha, beta, and/or gamma radiation. The Measurements Applications and Development Group at Oak Ridge National Laboratory compared the performance of several hand-held detectors commonly used to detect DU in soil (Coleman and Murray, 1999). For surface soils, scanning and fixed in situ measurements with gamma radiation scintillators have been effective. Due to the low-energy photon emission of DU, the Field Instrument for Detection of Low Energy Radiation (or FIDLER) is optimal. The detection of DU below surface using survey meters is inhibited by the absorption of alpha and beta particles in the soil. Handheld gamma ray spectrometers may detect DU below the surface, but the lack of a high-energy, high-yield gamma-ray emission by U-238 reduces the effectiveness of this technique for field identification and survey (Depleted Uranium Technical Brief, USEPA, 2006).

7.7.4.2. Fixed Laboratory Tests. Several laboratory methods are available for quantitation of uranium. Some of these analytical methods provide isotopic information. The PDT should determine if quantitation of uranium isotopes is needed or whether quantitation of total uranium is sufficient. Chemical methods include kinetic phosphorescence analysis (KPA), fluorimetry, and ICP-MS. Radiological methods include alpha spectroscopy, gamma spectroscopy, delayed neutron counting, and instrumental neutron activation analysis. Information on sample preparation and analytical methods for uranium may be found in the Multi-Agency Radiological Laboratory Analytical Protocols Manual (http://www.epa.gov/radiation/marlap/manual.html). The most common instrumentation used commercially for the identification and quantification of uranium and uranium isotopes are KPA, alpha spectroscopy, and ICP-MS. Depending on the selected analytical method, uranium and uranium isotope concentrations may be reported in activity units (e.g., picocuries per liter) or mass units (e.g., microgram per kilogram). The PDT should consider applicable project action levels and decide during project planning how the results of uranium and uranium isotopes should be reported. The advantages and disadvantages of the primary analytical methods are summarized in Table 7-11.

Table 7-11: Fixed Laboratory Tests for Uranium and Uranium Isotopes

<table>
<tr><th>Method Number</th><th>Title</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>ASTM D5174</td><td>Standard Test Method for Trace Uranium in Water by Pulsed-Laser Phosphorimetry</td><td>• Rapid and inexpensive determination of total uranium</td><td>• Does not provide isotopic information</td></tr>
<tr><td>SW6020A</td><td>Analysis of Metals by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)</td><td rowspan="2">• Direct mass measurement with ability to detect and separate U-233, U-234, U-235, U-236, and U-238.<br>• Lowest detection limits (other than for U-234) and lowest uncertainty for percent U enrichment calculations</td><td rowspan="2">• Small (1 gram [g]) typical aliquot size leads to replication issues if sample matrix is heterogeneous.</td></tr>
<tr><td>ASTM C1345</td><td>Standard Test Method for Analysis of Total and Isotopic Uranium and Total Thorium in Soils by Inductively Coupled</td></tr>
</table>

| Method Number | Title | Advantages | Disadvantages |
|---|---|---|---|
| | Plasma-Mass Spectrometry | • Lowest costs compared to alpha and gamma spectroscopy methods | |
| DOE HASL 300 A-01-R/U-02-RC/G-03[a] | Alpha Radioassay | • Provides a direct activity measurement with spectral feedback that enables easy determination of whether the sample is enriched, natural, or depleted uranium.<br>• Offers the lowest detection limit for U-234. | • Small (1 to 10 g) typical aliquot size leads to replication issues if sample matrix is heterogeneous.<br>• Higher costs than other methods due to required chemical separation to isolate U from other elements<br>• Achievable resolution prevents differentiation of U-233 from U-234 and U-235 from U-236 |
| USEPA Method EMSL-33[b] | Isotopic Determination of Plutonium, Uranium, and Thorium in Water, Soil, Air, and Biological Tissue (via Alpha Spectrometry) | | |
| ORISE Method AP11[c] | Sequential Determination of the Actinides in Environmental Samples Using Total Sample Dissolution and Extraction Chromatography | • Alpha spectrometry variation for samples with matrix interference problems or where the sample is non-digestible or dissolvable after normal digestion methods. | |

a The DOE Health and Safety Laboratory (HASL) methods may be found at the following Internet locations:
http://www.nbl.doe.gov/htm/EML_Legacy_Website/ProcMan/Sect4/4_5-4U.pdf
http://www.nbl.doe.gov/htm/EML_Legacy_Website/ProcMan/Sect4/4_5-2.pdf
http://www.nbl.doe.gov/htm/EML_Legacy_Website/ProcMan/Sect4/4_5-5.pdf

b USEPA method EMSL-33 may be found at the following Internet location:
http://www.epa.gov/sam/pdfs/EPA-EMSL-33.pdf

c Oak Ridge Institute for Science and Education (ORISE) method AP11 may be found at the following Internet location:
http://www.epa.gov/sam/pdfs/ORISE-AP11.pdf

7.8. Chemical Agents and Agent Breakdown Products.

7.8.1. CAs are chemical compounds intended for use (to include experimental compounds) that, through their chemical properties, produce lethal or other damaging effects on human beings and are intended for use in military operations to kill, seriously injure, or incapacitate persons through their physiological effects. Excluded are research, development, test, and evaluation of dilute solutions, riot control agents, chemical defoliants and herbicides, smoke and other obscuration materials, flame and incendiary materials, and industrial chemicals (DASA-ESOH Interim Guidance for Chemical Warfare Materiel Responses, 1 Apr 2009). ABPs are formed by decomposition, hydrolysis, microbial degradation, oxidation, photolysis, and decontamination of CAs. The term ABPs also has been used incorrectly to describe co-contaminant impurities formed during the manufacture of CAs.

7.8.1.1. Earlier definitions of CAs differed from the current definition. TM 3-215, Military Chemistry and Chemical Agents defines CA as a solid, liquid, or gas, which, through its chemical properties, produces lethal or damaging effects on man, animals, plants, or materiel or produces a screening or signaling smoke.

7.8.1.2. Archival information on the historical use of CAs must be evaluated based on the definition of CAs in place at the time that the information was generated.

7.8.2. CWM are items configured as munitions containing a chemical compound that is intended to kill, seriously injure, or incapacitate a person through its physiological effects. CWM includes V- and G-series nerve agents or H-series (mustard) and L-series (lewisite) blister agents in other-than-munition configurations and certain industrial chemicals (e.g., hydrogen cyanide [AC], cyanogen chloride [CK], or carbonyl dichloride [called phosgene or CG]) configured as military munitions (DASA-ESOH, 2009).

7.8.3. Although not intended as CWM, due to their hazards, prevalence, and military-unique application, chemical agent identification sets (CAIS) that contain neat agent or dilute nerve agent are considered CWM. CWM does not include riot control devices, chemical defoliants, and herbicides; industrial chemicals (e.g., AC, CK, CG) not configured as a munition; smoke and other obscuration-producing items; flame- and incendiary-producing items; or soil, water, debris, or other media contaminated with low concentrations of CAs where no CA hazards exist (DASA-ESOH, 2009). Soil, water, debris, or other media contaminated with dispersed V- and G-series nerve agent, H- and HN-series blister agent, or L will be considered and managed IAW 40 CFR 266 Subpart M.

7.8.3.1. The DoD produced CAIS between the 1930s and 1960s for use in training military personnel to safely identify, handle, and decontaminate CA. Varieties of CAIS included identification or sniff sets, detonation sets, and bulk agent sets. These sets contained a variety of dilute or neat CA (e.g., mustard, Lewisite) or industrial chemicals (e.g., phosgene). In the late 1970s and early 1980s, the Army destroyed 21,458 CAIS that had not been issued for training. All nerve CAIS are believed to have been destroyed at that time.

7.8.3.2. CAIS that are determined to contain dilute CA (mixed with chloroform [EPA Hazardous Waste Number D002]) or industrial chemicals (such as phosgene [EPA Hazardous Waste Number P095]) are managed as hazardous waste. CAIS components that contain neat CA (CAIS K941 and CAIS K942) and any CAIS found to contain dilute nerve agent remain CWM. Sampling to determine contamination due to CAIS use should only be conducted in areas where CAIS vials are known to have been found. CAIS typically are found either as loose glass vials that cannot be detected reliably via geophysics or within a “Pig” storage container that could be detected with geophysics (i.e., if it was made from metal or had metal components) but that would almost certainly retain any chemical release (see U.S. Army Program Manager for Chemical Demilitarization, Chemical Agent Identification Sets (CAIS) Information Package, Nov 1995). Therefore, sampling to locate CAIS vials is not a viable strategy.

7.8.4. The following data sources provide guidance relevant to characterization of CAs and ABPs as MC:

a. DASA-ESOH Interim Guidance for Chemical Warfare Materiel (CWM) Responses and Related Activities, 1 April 2009

b. Army RI/FS Guidance, Nov 2009

7.8.4.1. The Deputy Assistant Secretary of the Army, Environmental, Safety, and Occupational Health also provides information for compliance with Chemical Weapons Convention (CWC) requirements (2009). For purposes of treaty issues, chemical weapons (CW) are defined as any munition or device containing or suspected of containing any chemical listed on one of three CWC schedules of chemicals.

7.8.4.2. To comply with the CWC requirements, the U.S. Army established the Non-Stockpile Chemical Materiel Program (NSCMP). The NSCMP addresses the destruction of CWM that is not part of the U.S. CW stockpile.

7.8.5. Choking agents are designed to impede a victim's ability to breath. They operate by causing a build-up of fluids in the lungs, which then leads to suffocation. Common choking agents include CG, diphosgene (DP), chlorine, and chloropicrin (PS). Table 7-12 lists the chemical names of the choking agents, their CAS registry numbers, and analytical methods that could be used for their detection. The following subsections summarize the primary fate and transport mechanisms for the choking agents and provide sampling recommendations.

7.8.5.1. CG. Phosgene (carbonyl chloride) was used extensively in World War I (WWI). It was used as a filler for mortar shells, bombs, rockets, and cylinders. It has been documented in munitions and CAIS vials on FUDS. CG is a colorless, nonflammable gas that smells like new-mown hay or grass. It condenses to a colorless liquid below 46 degrees Fahrenheit. CG is expected to hydrolyze in moist soil at a rapid rate. Hydrolysis products are hydrochloric acid and carbon dioxide ($CO_2$). Any CG that does not hydrolyze is expected to have high mobility in soil. Volatilization of CG from moist soil surface is also an important fate and transport mechanism. Based on the lack of persistence in soil or water, sampling of environmental media other than air is not recommended.

7.8.5.2. DP. Diphosgene (trichloromethyl chloroformate) was used by the British, Germans, and Japanese in WWI and WWII. It is unstable and converts to CG when catalyzed by metals. It is not documented as having been used on FUDS. Due to its instability, environmental sampling for DP is not recommended.

7.8.5.3. Cl. Cl was used extensively in early WWI. It later was used as an ingredient in the manufacture of other agents. Cl was used in mortar shells and cylinders. Cl is not documented as having been used in FUDS munitions. Analytical methods are available for free or total Cl in water, wastewater, and air. However, given the common practice of chlorine-based processes for drinking water disinfection, it would be difficult to distinguish Cl from munition sources. Therefore, environmental sampling for Cl is not recommended.

7.8.5.4. PS. Chloropicrin (trichloronitromethane) was used extensively in WWI. It was suitable for use in mortar shells, bombs, and airplane spray. It has been documented in CAIS vials on FUDS. Although the SAM Manual identifies analytical methods, sampling for PS at sites where it was used historically is not recommended due to its lack of persistence. This recommendation is reinforced by the potential presence of known non-DoD sources of PS, including fumigant and soil insecticide, as well as formation of PS as a disinfection byproduct by the addition of chlorine to water containing organic matter.

Table 7-12: Choking Agents

| Compound | Abbreviation | CAS Number | Determinative Method[a] | Analytical Technology |
|---|---|---|---|---|
| Phosgene (carbonyl chloride) | CG | 75-44-5 | OSHA Method 61 (air monitoring) | GC/NPD |
| Diphosgene (trichloromethyl chloroformate) | DP | 503-38-8 | N/A | N/A |
| Chlorine | Cl | 7782-50-5 | Method 4500-Cl G: DPD (Standard Methods for the Examination of Water and Wastewater. 21st Edition, APHA, AWWA, and WEF, 2005) | Colorimetric method |
| Chloropicrin (trichloronitromethane) | PS | 76-06-2 | SW8270D (solids analysis) | GC/MS |
| | | | USEPA 551.1 (water analysis) | GC/ECD with 2nd column or GC/MS confirmation |
| | | | OSHA Method PV2103 (air monitoring) | GC/ECD |

Note:

N/A = not available

OSHA = Occupational Safety and Health Administration

a The SAM Manual (Standardized Analytical Methods for Environmental Restoration Following Homeland Security Events, SAM 2012, EPA/600/R-12/555, July 2012) attributes the compounds to the analytical methods listed in the table; however, the compounds currently are not included explicitly in the methods. Limited commercial laboratory capacity is available for CA and ABP analyses.

7.8.6. The primary nerve agents are Tabun (GA), Sarin (GB), Soman (GD), Cyclosarin (GF), and VX. Nerve agents became part of the U.S. munitions inventory after WWII. Due to the nature of these munitions, their inventory was tracked carefully. Live-fire testing / training activities were far more limited compared to conventional (or other CA) activities. Very few FUDS have documented use of nerve agents. Based on instability and volatility, as validated with modeling, nerve agents are not anticipated to contaminate groundwater (USACHPPM, 1999). For sites with older releases (e.g., FUDS), nerve agent ABPs are more likely to be of environmental concern than the nerve agents themselves due to time elapsed since use, combined with the fate and transport properties of the nerve agents. Therefore, the primary focus for sites with suspected nerve agent use is for air monitoring for the nerve agent and media sampling for applicable ABPs. If analytical methodology is available for media sampling for the nerve agent and munitions containing the agent are found, then recommend sampling the media adjacent to where the nerve agent munitions are found. Table 7-13 lists the chemical names of the nerve agents and nerve agent ABPs, their CAS numbers, and analytical methods that could be used for their detection.

Table 7-13: Nerve Agents and ABPs

| Compound | Description | Abbreviation | CAS Number | Determinative Method[a] | Analytical Technology |
|---|---|---|---|---|---|
| **Nerve Agents** | | | | | |
| Tabun (dimethylamido-ethoxyphosphoryl cyanide) | Nerve agent | GA | 77-81-6 | SW8270D<br>TO-10A (air analysis) | GC/MS |
| Sarin (isopropyl methylphosphono-fluoridate) | Nerve agent | GB | 107-44-8 | SW8271/ ECBC SOP | GC/MS |
| Soman (pinacolyl methylphosphono fluoridate) | Nerve agent | GD | 96-64-0 | ECBC SOP | GC/MS |
| Cyclosarin (cyclohexyl methylphosphono-fluoridate) | Nerve agent | GF | 329-99-7 | ECBC SOP | GC/MS |
| o-Ethyl S-(2-diisopropylaminoethyl) methyl-phosphonothiolate | Nerve agent | VX | 50782-69-9 | SW8271/ ECBC SOP | GC/MS |
| **Nerve Agent Breakdown Products** | | | | | |
| Isopropyl methyl phosphonic acid | GB ABP | IMPA | 1832-54-8 | SW8321B/ ASTM E2866-12 (solids analysis)/ D7597-09 (aqueous analysis) | HPLC /LC-MS-MS |
| Methylphosphonic acid | GB, GD, and VX ABP | MPA | 993-13-5 | SW8321B/ ASTM E2866-12 (solids analysis)/ D7597-09 (aqueous analysis) | HPLC/LC-MS-MS |
| Dimethyl methyl phosphonate | GB simulant and precursor | DMMP | 756-79-6 | SW8321B | HPLC |
| Ethyl methylphosphonic acid | VX ABP | EMPA | 1832-53-7 | SW8321B/ ASTM E2866-12 (solids analysis)/ D7597-09 (aqueous analysis) | HPLC/LC-MS-MS |
| Diisopropyl methylphosphonate | GB ABP | DIMP | 1445-75-6 | SW8270D/ ASTM E2866-12 (solids analysis)/ D7597-09 (aqueous analysis) | GC/MS/ LC-MS-MS |
| Pinacolyl methylphosphonic acid | GD ABP | PMPA | 616-52-4 | SW8321B/ ASTM E2866-12 (solids analysis)/ D7597-09 (aqueous analysis) | HPLC/ LC-MS-MS |

| Compound | Description | Abbreviation | CAS Number | Determinative Method[a] | Analytical Technology |
|---|---|---|---|---|---|
| S-(2-diisopropylaminoethyl)-methylphosphonothioic acid | VX ABP | EA2192 | 73207-98-4 | SW8321B | HPLC |

a The SAM Manual (Standardized Analytical Methods for Environmental Restoration Following Homeland Security Events, SAM 2012, EPA/600/R-12/555, July 2012) attributes the compounds to the analytical methods listed in the table; however, the compounds currently are not included explicitly in the methods. Limited commercial laboratory capacity is available for CA and ABP analyses.

7.8.6.1. GA. Tabun (dimethylamidoethoxyphosphoryl cyanide) persists 1 to 2 days under average weather conditions. It is suitable for use in mortar shells, artillery shells, bombs, spray, and rockets. There is limited documented use of GA on FUDS.

7.8.6.2. GB. Sarin (isopropyl methylphosphonofluoridate) is nonpersistent. It is suitable for use in mortar shells, artillery shells, bombs, spray, and rockets. There is limited documented use of GB on FUDS.

7.8.6.3. GD. Soman (pinacolyl methylphosphonofluoridate) persists 1 to 2 days under average weather conditions. It is suitable for use in mortar shells, artillery shells, bombs, spray, and rockets. GD is not part of the U.S. chemical inventory.

7.8.6.4. GF. Cyclosarin (cyclohexyl methylphosphonofluoridate) is more persistent than the other nerve agents but was not mass produced due to the higher expense of production. GF is not part of the U.S. chemical inventory.

7.8.6.5. VX. VX (o-Ethyl S-(2-diisopropylaminoethyl) methylphosphonothiolate) persists 2 to 6 days. It is suitable for use in large caliber artillery shells, spray, rockets, and mines. There is limited documented use of VX on FUDS.

7.8.6.6. Nerve agent ABPs. Nerve agent ABPs are listed in Table 7-13.

7.8.7. The primary blood agents are AC, CK, and arsine (SA). Table 7-14 lists the chemical names of the blood agents, their CAS numbers, and analytical methods that could be used for their detection. The following subsections summarize the primary fate and transport mechanisms for the blood agents and provide sampling recommendations.

7.8.7.1. AC. Hydrogen cyanide is an industrial chemical that is considered CWM in a weaponized form. It is unstable unless in a very pure form. It is suitable for use in mortar shells, bombs, and rockets. There is limited documented use of AC-containing munitions on FUDS. AC is highly volatile and has high water solubility. It has a vapor-phase degradation half-life of 530 days. Based on the lack of persistence in soil or water and lack of methodology / commercial laboratory support, sampling environmental media other than air is not recommended

7.8.7.2. CK. Cyanogen chloride has limited stability and polymerizes to cyanuric chloride (cyclic). It is suitable for use in mortar shells, bombs, rockets, and grenades. CK has been used at FUDS in munitions and in CAIS kits. Releases of CK would exist as a gas in atmospheric conditions. CK is extremely volatile and hydrolyzes rapidly in water. CK is formed during water treatment by chlorination and also is used as a fumigant. Based on its volatility, speed of hydrolysis, and lack of commercial laboratory support, sampling environmental media other than air is not recommended.

Table 7-14: Blood Agents

| Compound | Description | Abbreviation | CAS Number | Determinative Method[a] | Analytical Technology |
|---|---|---|---|---|---|
| Hydrogen cyanide | Blood agent | AC | 74-90-8 | NIOSH 6010 (air monitoring) | IC |
| Cyanogen chloride | Blood agent | CK | 506-77-4 | TO-15 (air monitoring) | GC/MS Purge-and-trap |
| Arsine | Blood agent | SA | 7784-42-1 | SW 6010C (soil) | ICP/AES |
| | | | | SW 6020A (aqueous) | ICP/MS |
| | | | | NIOSH 6001 (air monitoring) | GFAA |

Note:

NIOSH = National Institute for Occupational Safety and Health

a The SAM Manual (Standardized Analytical Methods for Environmental Restoration Following Homeland Security Events, SAM 2012, EPA/600/R-12/555, July 2012) attributes the compounds to the analytical methods listed in the table; however, the compounds currently are not included explicitly in the methods. Limited commercial laboratory capacity is available for CA and ABP analyses.

7.8.7.3. SA. Arsine is unstable in uncoated metal containers. It ignites easily and, thus, cannot be used in shells. Therefore, its use appears to have been limited to research. There are isolated cases of FUDS with documented use. Based on its volatility and the lack of specificity of the available analyses, which measure SA as total arsenic, sampling of environmental media is not recommended as a way to identify SA contamination. If SA is identified as a potential MC based on analysis of a neat compound in a container, then analysis of total arsenic may be the only way to determine if there is SA contamination.

7.8.8. Most blister agents fall into one of three groups: sulfur mustards, nitrogen mustards, and lewisite. Blister agent use began in WWI. Training with blister agents included CAIS familiarization training and decontamination training. Sampling locations for blister agents should be tied to MEC finds and/or based on aerial photograph interpretation to locate likely decontamination training areas. The analytical suite in decontamination areas used from the 1930s onward also should include chlorinated solvents because several of the decontaminating agents (e.g., chlorinating compound 1 or decontaminating agent, non-corrosive [DANC] – used up until the 1970s) contained these compounds (https://www.cbrniac.apgea.army.mil/Documents/vol10_num1.pdf). Based on instability and volatility, as validated with modeling, blister agents are not anticipated to contaminate groundwater (see Appendix E, USACHPPM, 1999). Therefore, groundwater sampling is not recommended for blister agents. Table 7-15 lists the chemical names of the blister agents and blister agent ABPs, their CAS numbers, and analytical methods that could be used for their detection.

Table 7-15: Blister Agents and ABPs

| Compound | Description | Abbreviation | CAS Number | Determinative Method[a] | Analytical Technology |
|---|---|---|---|---|---|
| **Blister Agents** | | | | | |
| Sulfur mustard (bis(2-chloroethyl)sulfide) | Blister agent | H, HD | 505-60-2 | SW 8271 / ECBC SOP | GC/MS |
| Lewisite (dichloro(2-chlorovinyl)arsine) | Blister agent | L | 541-25-3 | ECBC SOP | GC/MS[b] |
| Nitrogen mustard (bis(2-chloroethyl)ethylamine) | Blister agent | HN-1 | 538-07-8 | SW 8270D/ ECBC SOP | GC/MS |
| Nitrogen mustard (bis(2-chloroethyl)methylamine) | Blister agent | HN-2 | 51-75-2 | SW 8270D/ ECBC SOP | GC/MS |
| Nitrogen mustard (tri(2-chloroethyl)amine) | Blister agent | HN-3 | 555-77-1 | SW 8270D/ ECBC SOP | GC/MS |
| **Blister ABPs** | | | | | |
| 1,4-Dithiane | HD ABP | | 505-29-3 | SW 8270D | GC/MS |
| 1,4-Thioxane | HD ABP | | 15980-15-1 | SW 8270D | GC/MS |
| Thiodiglycol | HD ABP | TDG | 111-48-8 | SW 8321B or ECBC SOP/ ASTM E2787-11 (solids analysis)/ D7598-09 (aqueous analysis) | LC-MS-MS |
| 2-Chlorovinyl arsenous acid | L ABP | CVAA | 85090-33-1 | ECBC SOP | GC/MS[b] |
| 2-Chlorovinyl arsenous oxide | L ABP | CVAO | 3088-37-7 | ECBC SOP | GC/MS[b] |
| Triethanolamine | HN-3 ABP | TEA | 102-71-6 | SW 8321B or ECBC SOP/ ASTM D7599-09 (aqueous samples) | LC-MS-MS |
| Diethanolamine | HN-1 ABP | DEA | 111-42-2 | SW 8321B or ECBC SOP | LC-MS-MS |
| N-ethyldiethanolamine | HN-1 ABP | EDEA | 139-87-7 | SW 8321B or ECBC SOP | LC-MS-MS |

Note:
CVAO = lewisite oxide
ECBC = Edgewood Chemical Biological Center
a The SAM Manual (Standardized Analytical Methods for Environmental Restoration Following Homeland Security Events, SAM 2012, EPA/600/R-12/555, July 2012) attributes the compounds to the analytical methods listed in the table; however, the compounds currently are not included explicitly in the methods. Limited commercial laboratory capacity is available for CA and ABP analyses. b L, CVAA, and CVAO must be derivatized and form the same derivative. They are analyzed and reported together.

7.8.8.1. H, HD. Sulfur mustard (bis(2-chloroethyl)sulfide) was the only blister agent in major use in WWI. It persists 1 to 2 days in average weather conditions and may persist up to a week or more in very cold conditions. H is suitable for use in land mines, spray tanks, bombs, artillery shells, mortar shells, and rockets. Although often referred to as mustard "gas," it is actually an oily liquid. If released to the air, sulfur mustard exists as a vapor. The vapor will be degraded by hydroxyl radicals with an estimated half-life of a one-half hour. If released to soil, H is expected to have high mobility. It can be highly persistent under conditions of low temperature and moisture. It is expected to volatilize from moist soil surfaces but not from dry surfaces. If released into water, H is not expected to adsorb to suspended solids and sediment; rather, it is expected to volatilize from water surfaces. Because H has limited solubility in water, hydrolysis is limited by its slow rate of solution. During the dissolution process, the outer surfaces of H droplets form stable polymerized hydrolysis product. Without agitation, this polymerized hydrolysis product creates a boundary layer that interferes with the dissolution of sulfur mustard in water. Without agitation, bulk H may persist in water for up to several years. The H ABPs 1,4-dithiane and 1,4-thioxane should be analyzed together with H. Analysis for thiodiglycol (TDG) is warranted only if sulfur mustard, 1,4-dithiane, or 1,4-thioxane are detected due to the numerous other sources of TDG (Munro et. al, 1999). If sampling for sulfur mustard and/or its ABPs is required, then laboratory limits of quantitation must be below the appropriate health-based environmental screening levels (HBESLs), as illustrated in Figure 8-17.

7.8.8.2. HN-1, HN-2, HN-3. The three nitrogen mustards, HN-1 (bis(2-chloroethyl)ethylamine), HN-2 (bis(2-chloroethyl)methylamine), and HN-3 (tri(2-chloroethyl)amine), were not manufactured in great quantities in the United States and were not stockpiled as part of the U.S. CW inventory. The only documented presence of nitrogen mustards on FUDS is in association with CAIS vials (HN-1 and HN-3 only). All three compounds are colorless, odorless, liquids when freshly distilled. Within days after distillation, HN-3 darkens and deposits crystalline solids. HN-1 is suitable for use in land mines, artillery shells, mortar shells, bombs, rockets, and spray tanks. It is slightly less persistent than sulfur mustard. HN-2 is highly unstable and is no longer considered to be viable for use as CWM. HN-3 is the most stable of the three compounds and is suitable for use as a bomb filling, even under tropical condition. It also is suitable for use in land mines, artillery shells, mortar shells, bombs, rockets, and spray tanks. The nitrogen mustards are unstable in the presence of light and heat. They are only slightly volatile and are only slightly soluble in water. The major fate process in soil and water is expected to be hydrolysis. Table 7-15 lists some of the major hydrolysis products for HN-1 and HN-3.

7.8.8.3. L. Lewisite (dichloro(2-chlorovinyl)arsine) is an organic arsenical compound. The only documented presence of L on FUDS is in association with CAIS vials. L is suitable for use in land mines, spray tanks, bombs, artillery shells, mortar shells, and rockets. It is slightly less persistent than H and does not persist under humid conditions due to its rapid rate of hydrolysis, which results in the formation of CVAA. Formation of CVAO and lewisite polymer may also occur. L, CVAA, and CVAO are all derivatized in the same reaction as part of the analytical procedure and, thus, are reported together as a detection of L.

7.8.9. Incapacitating agents could have been used for situations where the military required control but did not desire harm to population and/or troops. They also could have been used for covert operations to confuse defense or retaliatory forces. Incapacitating agents may cause temporary physical disability, such as paralysis, blindness, or deafness. They may also produce "temporary mental aberrations" such as hallucinations or disorientation (TM 3-215).

The only incapacitating agent successfully weaponized and stockpiled for potential use is 3-quinuclidinyl benzilate (BZ). BZ was produced primarily in the 1950s and 1960s. Demilitarization of BZ began in 1988 and is complete. BZ was distributed in generator clusters, grenades (also referred to as canisters), and cluster bombs. The environmental fate of BZ in soil, water, and on most surfaces is described as "extremely persistent," but no quantitative description is available. If a site has documented use of munitions containing BZ, then analyses of environmental media may be appropriate. (See Table 7-16 for analytical methods).

Table 7-16: Incapacitating Agent

| Compound | Abbreviation | CAS Number | Determinative Method[a] | Analytical Technology |
|---|---|---|---|---|
| 3-Quinuclidinyl benzilate | BZ | 6581-06-2 | SW 8321B | LC/MS |

a The SAM Manual (Standardized Analytical Methods for Environmental Restoration Following Homeland Security Events, SAM 2012, EPA/600/R-12/555, July 2012) attributes the compounds to the analytical methods listed in the table; however, the compounds currently are not included explicitly in the methods. Limited commercial laboratory capacity is available for CA and ABP analyses.

7.8.10. The following data sources provide information on fixed laboratory chemical analysis tests of CAs and ABPs:

a. USEPA SW846 Manual (http://www.epa.gov/osw/hazard/testmethods/sw846/)

b. USEPA/600/R-10/122, Standardized Analytical Methods for Environmental Restoration Following Homeland Security Events (SAM Manual), SAM 2012, EPA/600/R-12/555 , July 2012 (http://www.epa.gov/sam/)

7.8.10.1. To conduct CA analyses, a laboratory must participate in the Chemical Agent Standard Analytical Reference Material program to acquire reference standards and must be DoD Environmental Laboratory Accreditation Program (ELAP) certified. These requirements apply to both field and fixed-base laboratories. Analysis of ABPs requires only DoD ELAP certification. However, samples being analyzed for ABPs may also contain CA; therefore, the same safety protocols as for CA analyses are recommended.

7.8.10.2. Few methods published by the USEPA exist for CAs or ABPs, other than SW8271 for nerve agents and sulfur mustard (for solid and aqueous samples by GC/MS electron impact). The SAM Manual attributes various CA and ABPs to USEPA methods (see Tables 7-12 through 7-16); however, compounds attributed to methods other than SW8271 are not included explicitly in the published methods. Analytical methods for several ABPs have been developed by ECBC. Limited commercial laboratory capacity is available for CA and ABP analyses.

7.8.10.3. The CWM DC provides specialized support to assist HQUSACE, USACE Commands, FOA, and laboratories by executing CW activities and maintaining state-of-the-art technical expertise for all aspects of CWM DC response activities. The CWM DC is the only Design Center authorized to execute any phase of a CWM project.

7.9. Riot Control Agents.

7.9.1. Riot control agents are characterized by very low toxicity (chronic or acute) and a short duration of action. There are two mechanisms of action for riot control agents: vomiting agents and tear agents.

7.9.1.1. Vomiting Agents. Vomiting agents, known as sternutators, are solids that, when heated, vaporize and then condense to form toxic aerosols. These agents typically are used for mob and riot control but historically also have been used on battlefields. The three primary vomiting agents are adamsite (DM), diphenylchloroarsine (DA), and diphenylcyanoarsine (DC). Table 7-17 lists the chemical names and common names of the vomiting agents as well as their CAS numbers.

Table 7-17: Vomiting Agents

| Compound | Description | Abbreviation | Common Name | CAS Number |
|---|---|---|---|---|
| Phenarsazine chloride | Vomiting agent | DM | Adamsite | 578-94-9 |
| Diphenylchloroarsine | Vomiting agent | DA | Clark I | 712-48-1 |
| Diphenylcyanoarsine | Vomiting agent | DC | Clark 2 | 23525-22-6 |

7.9.1.1.1. DM. Adamsite (phenarsazine chloride) was produced and stockpiled by the United States towards the end of WWI. DM is known to have been included in two CAIS: CAIS K955 and Navy X set X549. CAIS K955 was issued from the late 1930s through WWII and contained one glass bottle with 15 g DM. Navy X549 set contained two vials with 15 g each of DM and was issued from WWII through the Korean Conflict. DM also is known to have been used in irritant hand grenades, which contained 0.13 pounds of DM and 0.13 pounds of tear gas (CN). It also was used in gas candles (2 pounds), which were metals tubes containing a composition of DM that produced smoke by vaporizing a smoke-producing oil. If released to air, DM is anticipated to remain in the particulate phase without photolyzing (HSDB, 2012). If released to soil, it is expected to be neither mobile nor volatile (from moist or dry surfaces). It has been reported to hydrolyze slowly (HSDB, 2012). If released to water, it is expected to adsorb to suspended solids and sediment but is not expected to be volatile from water surfaces. Potential for bioconcentration in aquatic organisms is high. If vials believed to contain DM are found with vials containing CA, the CA vials likely will drive any cleanup requirements. In the unlikely case that DM vials are found alone, it is recommended that sampling be performed for total arsenic as a means of determining whether any residual organo-arsenical residue remains, in lieu of conducting analytical research to confirm DM unless the circumstances warrant the time and expense associated with testing for DM.

7.9.1.1.2. DA. Diphenylchloroarsine was used by the Germans in WWI and WWII. It is not likely to be encountered on former military sites in the United States.

7.9.1.1.3. DC. Diphenylcyanoarsine was used by the Germans in WWI and WWII; the Japanese used DC in WWII. It is not likely to be encountered on former military sites in the United States.

7.9.1.1.4. Fixed Laboratory Tests for Vomiting Agents. Standards and published methods for the vomiting agents are not available. The following journal article documents successful analysis of DA and DC using GC-ECD and DM using HPLC: Rainer Haas, Torsten C. Schmidt, Klaus Steinbach, Eberhard von Löw, Chromatographic determination of phenylarsenic compounds, Fresenius J Anal Chem (1998) 361: 313-318. Consultation with ECBC is recommended if analysis is required.

7.9.1.2. Tear Agents. Tear agents, known as lachrymators, stimulate the corneal nerves in the eyes to cause tears to flow and also may cause skin irritation. The use of tear agents is limited to training and riot control. On battlefields, tear agents are of limited value due to the availability of protective equipment. Tear agents include chloroacetophenone (CN; also known as mace or tear gas), CN variants, bromobenzylcyanide (BBC or CA), bromoacetone (BA), oleoresin capsicum (OC; also known as pepper spray), o-chlorobenzalmalonitrile (CS), CS variants, and dibenzoxazepine (CR). BBC (CA) and BA have no documented historical use at FUDS; no data are available for active military installations. The Army approved CR for use in 1974. Primarily military police units use OC at military installations. CN and CS, along with some of their variants, historically have been used most widely by the military. Table 7-18 lists the chemical names and common names of the tear agents as well as their CAS numbers.

7.9.1.2.1. CN. Mace (2-chloroacetophenone) is known to have been included in two CAIS: CAIS K955 and Navy X set X546. CAIS K955 was issued from the late 1930s through WWII and contained one glass bottle with 15 g CN. Navy X546 set contained two vials with 15 g each of CN and was issued from WWII through the Korean Conflict. CN also is known to have been used in grenades, mortar shells, and candles. Three CN variants also were used: CNC (CN in chloroform), CNS (CN and PS mixed in chloroform), and CNB (CN in benzene and carbon tetrachloride). These three variants of CN were suitable for use in spray tanks, mortar shells, bombs, and grenades. CN exists solely in the vapor phase if released to the air. It has a photolysis reaction half-life of approximately 8 days. If released to the soil, CN is highly mobile and volatilizes from moist soil but not from dry soil. If released to water, CN tends not to adsorb to sediment or soil and volatilizes. Hydrolysis occurs, but slowly. If vials believed to contain CN are found with vials containing CA, the CA vials likely will drive any cleanup requirements. In the unlikely case that CN vials are found alone or that CN munitions are found, use best judgment to determine the necessity of finding a means to confirm the presence or absence of CN in media. USAPHC or ECBC may be consulted for assistance.

7.9.1.2.2. CS. The Army replaced the use of CN with o-chlorobenzalmalonitrile (also known as o-chlorobenzylidene malonitrile) in 1959. There are three CS variants: CS1, a powder, contains 95% CS and 5% silica aerogel; CS2, an aerosol, contains 94% CS formulated in a mixture of 5% Cab-0-Sil® colloidal silica and 1% hexamethyldisilizane; CSX, a liquid, contains 1 g of CS per 99 g of trioctyl phosphate. Munitions containing CS include grenades, capsules, and projectiles. CS1 has been used in grenades and bulk dispensers. CS exists in both the vapor phase and as particulates if released to the air. It has a photochemical degradation reaction half-life of approximately 110 hours in the vapor phase. Particulates may be removed by wet and dry deposition. If released to the soil, CS has low mobility and does not volatilize. If released to water, CS tends to adsorb to sediment or soil and does not volatilize. Hydrolysis is the primary degradation pathway for soil and groundwater. Considering that environmental fate information indicates that past releases are likely to have undergone hydrolysis and that there is limited laboratory capacity for CS analyses, best judgment should be applied to determine the necessity of finding a means to determine the presence or absence of CS in media if CS munitions are found on a site. USAPHC or ECBC may be consulted for assistance.

Table 7-18: Tear Agents

| Compound | Abbreviation | Common Name | CAS Number |
|---|---|---|---|
| o-Chlorobenzylidene malononitrile | CS | o-Chlorobenzalmalonitrile | 2698-41-1 |
| 1-Bromo-2-Propanone | BA | Bromoacetone | 598-31-2 |
| alpha-Bromobenzene-acetonitrile, Camite | BBC, CA | Bromobenzylcyanide | 5798-79-8 |
| 2-Chloroaceto-phenone, Mace, 2-Chloro-1-phenylethanone | CN | Chloroacetophenone | 532-27-4 |
| Capsaicin (primary active ingredient) | OC | Oleoresin Capsicum "Pepper Spray" | 404-86-4 |
| Dibenz(b,f)[1,4] oxazepine | CR | Dibenzoxazepine | 257-07-8 |

7.9.1.2.3. Fixed Laboratory Tests for Tear Agents. NIOSH methods are available to analyze for CS (NIOSH P&CAM 291, GC-FID) and CN (NIOSH P&CAM 304, HPLC) in air, but there are no published methods for CS and CN in other media. There are no published analytical methods for the other tear agents. There is no commercial laboratory capability available at this time for any tear agents.

7.10. Incendiaries.

7.10.1. General. Incendiaries are munitions that are used to set fire to buildings, industrial installations, ammunitions, fuel dumps, or other items. There are three categories of incendiaries: oil, metal, and a combination of oil and metal.

7.10.2. Oil Incendiaries. Oil incendiaries are based upon gasoline and may contain either straight gasoline or blends of gasoline with fuel oil and kerosene. Fuel mixtures may be used in a normal liquid form or a thickened form. Unthickened fuel was used in flamethrowers or when thickened fuel was not available. Thickened fuel was used in flamethrowers and all oil incendiary bombs. Fuel thickeners include the following:

a. M1 thickener (Napalm, Standard B) – Made up of 50% coconut oil, 25% napthenic acids, and 25% oleic acid; thickener added at 2% to 12% to fuel

b. M2 thickener (Napalm, Standard for U.S. Air Force only) – Made up of 95% M1 thickener and 5% devolatilized silica aerogel

c. M4 thickener – Made from di-acid aluminum soap of isooctanoic acids

d. Isobutyl methacrylate (IM incendiary oil, type 1) – Made up of 5.0% isobutyl methacrylate, 3.0% stearic acid, 2.0% calcium oxide, 88.75% gasoline, 1.25% water

e. Natural rubber

Other additives to oil incendiaries include peptizers and igniters. Peptizers are substances added to improve the dispersal of the thickener in the fuel. Examples include water, octoic acid, and cresylic acid (mixtures of xylenols and cresols). Cresylic acid is the preferred peptizer, used at one part cresylic acid to four parts of thickener. Igniters include white phosphorus (WP; primary type), sodium (used for munitions dropped over water), and red phosphorus (RP)-tipped metal matches (used for flamethrowers). If an area is identified as having intact or leaking oil incendiary munitions, consider sampling based on state requirements for fuel releases. Consider the potential presence of other non-DoD fuel sources to maintain appropriate attribution of site contaminants.

7.10.3. Metal Incendiaries. The primary metal incendiaries are magnesium, thermite (TH), and thermate (TH3 or TH4).

7.10.3.1. Magnesium. Magnesium is used in powdered and solid form or as an alloy. The alloy contains 4.45% aluminum, 1.24% zinc, and 94.31% magnesium. The combustion product of magnesium incendiaries is magnesium oxide. Magnesium incendiaries have been used in small arms, hand grenades, and bombs.

7.10.3.2. TH. Thermite is a mixture of approximately 73% iron oxide and approximately 27% powdered or granular aluminum. TH has been used in hand grenades and bombs.

7.10.3.3. TH3 or TH4. Thermate contains thermite with various additives. TH3 contains 68.7% thermite, 29.0% barium nitrate, 2.0% sulfur, and 0.3% oil (binder). TH4 contains 51% iron oxide, 22% barium nitrate, 19% aluminum (granular), 3% aluminum (grained), and 5% polyester resin (Laminac 4116). TH3 and TH4 have been used in hand grenades and bombs.

7.10.3.4. Metals. The primary metals that comprise the metal incendiaries are aluminum, magnesium, iron, and barium; zinc is only a minor component. Sampling to determine whether the primary metals are present may be reasonable at a site where metal incendiary use is suspected or confirmed, particularly in environmentally sensitive areas. A background study to determine site-specific background metals concentrations would be recommended (see discussion in Chapter 8).

7.10.4. Oil and Metal Incendiaries. There are two main types of oil and metal incendiaries: PT1 and PTV. PT1 contains 49% type C "goop" (paste made of magnesium oxide, carbon, petroleum distillate, and asphalt), 3% isobutyl methacrylate polymer AE, 10% coarse magnesium, 3% petroleum oil extract, 30% gasoline, and 5% sodium nitrate. PTV is an improved version of PT1 composed of 5% polybutadiene, 60% gasoline, 28% magnesium, 6% sodium nitrate, and 0.1% p-aminophenol. PT1 and PTV are suitable for use in incendiary bombs. The PDT should consider using analytical methods for petroleum hydrocarbons and metals as discussed in the recommendations for oil incendiaries and metal incendiaries. For munitions containing PT1, an evaluation of polynuclear aromatic hydrocarbons (PAHs) also may be appropriate given the asphalt content.

7.11. Smokes and Obscurants.

7.11.1. Obscurants are anthropogenic or naturally occurring particles that are suspended in air and block or weaken transmission of a particular part or parts of the electromagnetic spectrum, such as visible and infrared radiation or microwaves. Smoke is an artificially created obscurant normally produced by burning or vaporizing a material and also can be used for signaling purposes.

7.11.2. Smoke may be delivered via projection or generation with reliance on steering winds to deliver the smoke to a target. Projected smoke is produced by artillery or mortar munitions, naval gunfire, helicopter-delivered rockets, bombs, and generator smoke from fixed-wing aircraft. Generated smoke is produced by smoke pots, smoke grenades, and smoke generators.

7.11.3. Screening smokes from WWI include sulfur trioxide, oleum, chlorosulfonic acid, sulfuryl chloride, titanium tetrachloride (FM), WP, RP, tin tetrachloride (KJ; stannic chloride), silicon tetrachloride / ammonium anhydride, and Berger Mixture (contains zinc dust, carbon tetrachloride, sodium chlorate, ammonium chloride, and magnesium carbonate). Screening smokes used from WWII through the Korean Conflict include sulfur trioxide-chlorosulfonic acid solution (FS), hexachloroethane and zinc oxide mixture (HC), oil smoke/fog oil, plasticized white phosphorus (PWP), and colored smoke. More recently used screening smokes include titanium dioxide, polyethylene glycol (a recently proposed alternative to HC), teraphthalic acid (used in the AN-M8 grenade), infrared smokes (EA-5763 and EA-5769, which are brass flakes used in XM76/M76 smoke grenades), and synthetic graphite flakes/powder (commercially known as Micro-260 and KS-2). Historically, the smokes that were used most commonly are FS, FM, WP, RP, HC, and oil smoke. Table 7-19 lists the chemical names and common names of the screening smokes as well as their CAS numbers.

Table 7-19: Smokes

| Compound | Description | Abbreviation | Common Name | CAS Number |
|---|---|---|---|---|
| Chlorosulfonic acid, with Sulfur trioxide make up FS | Smoke | FS | Chlorosulfonic acid | 7790-94-5 |
| Hexachloroethane | Smoke | HC | Hexachloroethane | 67-72-1 |
| Amorphous phosphorus | Smoke | RP | Red phosphorus | 7723-14-0 |
| Silicon tetrachloride | Smoke | N/A | Silicon tetrachloride | 10026-04-7 |
| Sulfur trioxide, with chlorosulfonic acid, makes up FS | Smoke | N/A | Sulfur trioxide | 7446-11-9 |
| Stannic chloride | Smoke | KJ | Tin tetrachloride | 7646-78-8 |
| Titanium tetrachloride | Smoke | FM | Titanium tetrachloride | 7550-45-0 |
| WP aka Molecular Phosphorus; Elemental P (Valence State 0) - CAS# 7723-14-0 | Smoke | WP | White phosphorus | 12185-10-3 |

Note: N/A = no abbreviation for this compound

7.11.3.1. <u>FS</u>. Chlorosulfonic acid (45%) together with sulfur trioxide (55%) makes up FS. FS was used in portable cylinders, airplane tanks, and projectiles. FS is corrosive in the presence of moisture, limiting its use. Chlorosulfonic acid reacts rapidly with water, yielding hydrochloric and sulfuric acids. Therefore, hydrolysis is expected to occur in moist soil or air releases. Similarly, sulfur trioxide reacts rapidly with water to yield sulfuric acid, and hydrolysis is expected in moist soil and air releases. Because there is no compound that could be isolated from environmental media as clearly sourced to FS, analysis of environmental media is not appropriate. Rounds filled with FS trigger liquid-filled UXO requirements. Due to the corrosivity of FS, rounds containing FS that are disposed of in a Controlled Detonation Chamber (CDC) may trigger additional waste disposal requirements (i.e., RCRA characteristic for corrosivity) as well as operational concerns for the CDC.

7.11.3.2. FM. Titanium tetrachloride reacts immediately with water or water vapor (residence times in air or water are expected to be on the order of hours). All hydrolysis products eventually form titanium dioxide. Titanium dioxide is insoluble in water and may settle out in sediments. It is inert and is used in cosmetics and food products. Rounds with FM fill trigger liquid-filled UXO requirements. The only analytical methods available for FM analyze for total titanium (see SAM Manual and USACERL, TR 99/56). Detection of titanium is not definitive evidence of titanium tetrachloride release because titanium occurs naturally (approximately 0.6% of Earth's crust). The lack of a direct analytical method for titanium tetrachloride, coupled with FM's properties (i.e., high rate of hydrolysis and low toxicity of the ultimate hydrolysis product) support a recommendation to forego analysis for titanium unless a recent release is present.

7.11.3.3. WP. White phosphorus (elemental phosphorus, chemical formula $P_4$) has been used as filler in artillery shells (105 mm and 155 mm), tank guns (75 mm, 90 mm, and 105 mm), mortars (60 mm, 81 mm, and 4.2-inch), grenades, and aerial smoke systems (bombs, bomblets, and rockets). If released in water, WP reacts mainly with oxygen in the water to form phosphorous pentoxide ($P_4O_{10}$), the anhydride of phosphoric acid, which may persist for hours to days. Chunks of WP coated with protective layers may persist in water and soil for years if oxygen levels are low in the water or soil. In anoxic water, WP may react with water to form phosphine, which quickly moves from water to air before degrading to less harmful chemicals in less than 1 day. WP exhibits a slight bioaccumulation in fish. If released to soil or sediment, WP may persist for a few days before degrading to less harmful chemicals. It can develop crusts of protective coating and may be reactivated when the crust breaks, exposing WP to the atmosphere. If significant levels of WP are present in soil that is excavated, visible smoke may be observed. If visible smoke is observed, notify analytical laboratory and confirm willingness to accept for analysis. In deeper soil and the bottom deposits of surface water bodies, where little oxygen is present, WP may persist for centuries.

7.11.3.3.1. WP Regulatory Requirements. WP is regulated under several environmental laws. It is a hazardous substance under CERCLA and is reportable if more than 1 pound is released. WP is classified as a hazardous air pollutant under the CAA and is considered a RCRA reactive waste (USEPA Hazardous Waste Number D003). It is regulated under the CWA and may be subject to discharge limits. Because of these regulatory requirements, careful planning is required prior to conducting an investigation for WP. Planning considerations, to include disposal options, should be discussed in the appropriate project planning documents.

7.11.3.3.2. WP Sampling Considerations. If the PDT suspects that there may have been a WP release in an anoxic environment, environmental samples (especially sediment samples) should be collected. If any release would have been exposed to the air, it is unlikely that WP is still present, although it is not impossible due the potential formation of a crust that may prevent WP from reacting with oxygen. If samples emit smoke (e.g., samples are collected from an excavation of soil containing significant levels of WP or from residue after munitions have been detonated in place or in a contained detonation chamber), notify laboratory personnel and consult qualified DOT-trained personnel prior to sample shipment. There are specific considerations related to IS when collecting samples for WP analysis. Although IS has been proven successful with WP at Eagle River Flats, this situation was specific for sediments below the water column that were known to be contaminated and sediments that were heavily contaminated to determine particulate WP that would be available to dabbling ducks. If the project being evaluated has a similar CSM, it is recommended that the reader consult "Composite Sampling of Sediments Contaminated with White Phosphorus," Special Report 97-30 and consider contacting USACE CRREL for expert assistance related to WP. However, if sampling for WP where the site does not involve anoxic sediments, particularly if the site does not involve known contamination, IS sampling for WP is not recommended. This is primarily because sample processing that involves drying, grinding, or sieving should not be performed prior to analysis because of the potential hazard and loss of WP by sublimation and oxidation. Additionally, SW7580 preservation requirements are that soil samples be collected with minimal headspace and kept in the dark, so the sample containers in use for most IS (clean polyethylene bags) are inappropriate for WP. If a project is conducting IS for other analytes and WP is a desired analyte, the PDT should discuss plans for sample collection during TPP and document them in the project UFP-QAPP. There are several non-DoD uses and sources of WP. For instance, WP is used to produce phosphoric acid as well as other industrial chemicals used to make fertilizers, food and drink additives, cleaning compounds, and other products. Small amounts of WP also have been used in rat and roach poisons as well as in fireworks and matches.

7.11.3.3.3. Field Tests for WP. No field tests have been developed for WP, although the fixed laboratory test has been used on a limited basis in the field, to include use of solid-phase micro-extraction as discussed in SW7580.

7.11.3.3.4. Fixed Laboratory Tests for WP. Fixed laboratory tests for WP are all based on GC. The only published method for WP is SW7580, a GC method with an NPD. A GC/MS method is also available but is not published. NIOSH Method 7905 is available for air samples. Due to increased regulation of WP by the Drug Enforcement Agency, WP standards currently are unavailable from standards distributors; therefore, analytical capabilities for this compound are very limited. Contact the EM CX for methodology recommendations and laboratory availability.

7.11.3.4. PWP. PWP is a formulation of WP and other compounds (e.g., butyl rubber) to stabilize the smoke agent fill and slow the burning rate. WP and RP have been plasticized with a styrene-butadiene rubber for use in munitions. The styrene-butadiene rubber is inert; however, it is capable of supporting combustion when it is divided finely. It is very slowly degraded in the atmosphere through reaction with ozone or attack by microorganisms. Reaction products include lower molecular weight hydrocarbons and $CO_2$. Production of PWP was halted in 1965. The sampling recommendations for PWP are the same as those for WP. However, with the addition of the plasticizer, the WP crust is more likely to form.

7.11.3.5. RP. Red phosphorus (amorphous phosphorus, chemical formula $(P_4)_n$) is not spontaneously flammable, requiring ignition to burn and make smoke. It is less incendiary than either WP or PWP, making it safer for use in smaller cartridges (e.g., 40 mm grenades). RP is combined with one of the following for distribution: felt, butyl rubber, or polymer epoxy binders. Under moist conditions, RP reacts to produce various phosphoric acids. In the environment, RP slowly degrades by disproportionation and hydrolysis to phosphorus acids and phosphine ($PH_3$). Phosphine is very reactive and usually undergoes rapid oxidation. The final products, phosphates, are nontoxic. In wastewater, RP adsorbs to sewage sludge. RP is harmful to aquatic organisms. In TR 99/56, U.S. Army Construction Engineering Research Laboratory recommends using the same method for RP as for WP (SW 7580). However, no commercial laboratory capability is known for this compound. Based on RP's reaction products (phosphoric acids), which are mostly not distinguishable via laboratory analysis, and the lack of available laboratory capacity, characterization of sites for RP is not recommended.

7.11.3.6. KJ. Americans and others used tin tetrachloride (stannic chloride) in WWI and WWII. The Americans used KJ less frequently than other tetrachlorides. KJ is a fluid that fumes in air and hydrolyzes into stannic hydroxide (visible smoke). It was used both alone and in combination with CA fills, such as agent NC (80% chloropicrin and 20% KJ). When added to CA fills, it increased the visibility of the CA cloud and increased the ability of the CA to penetrate the charcoal canister in protective masks. The sampling and analysis recommendations for KJ are the same as those for FM described above.

7.11.3.7. HC (Hexachloroethane) Mixture. The composition of HC changed over time. It was developed during WWI (though not used by Americans) as a composition containing carbon tetrachloride and zinc. At the beginning of WWII, the composition changed to HC, ammonium chloride, and perchlorate salt. In 1940, perchlorate was no longer available; chlorates were tested in its place but proved too hazardous. This led to the current day mixture, which contains HC, grained aluminum, and zinc oxide. A pyrotechnic starter mixture usually ignites the burning reaction. The mixture reacts with moisture in the air to form a zinc chloride ($ZnCl_2$) solution in tiny droplets, which results in smoke. HC smoke was disseminated via smoke pots, grenades, 105 mm cartridges, and 155 mm projectiles. In the late 1990s, the USACHPPM determined that M5 HC smoke pots exhibit the RCRA toxicity characteristic for lead and possibly for cadmium depending on the individual pot tested (USACHPPM Memorandum, Subject: Hazardous Waste Study No. 37-7016-97/98, Feb 1998 [available from EM CX upon request]). The memorandum describing the study noted that potential sources for lead included lead solder and a small amount of lead thiocyanate in the flash charge. Potential cadmium sources were identified as impurities in the zinc oxide filler and cadmium used in electroplating some components. No methods exist to determine zinc chloride, and analysis for zinc does not accurately reflect zinc chloride concentrations due to background zinc levels in soil. If any HC smoke pots are found at a site, it is recommended that they be characterized for RCRA metals. The PDT should use professional judgment in deciding whether to sample for HC. Analyses for zinc should evaluate background concentrations carefully.

7.11.3.8. Oil Smoke. Vaporizing fuel oils in mechanical smoke generators or engine exhausts may produce oil smoke. It was used widely in WWII, where the first means of production was the M1 mechanical smoke generator. Two commonly used oils are fog oil (standard grade fuel-2; a light-duty lubricating oil equivalent to a SAE 20-grade motor oil) and diesel fuel. If an area is identified as having intact or leaking oil smoke munitions, the PDT should consider sampling based on state requirements for fuel releases. Consider the potential presence of other non-DoD fuel sources to maintain appropriate attribution of site contaminants.

7.12. Other Types of Munitions Constituents.

7.12.1. Illumination Rounds. Illumination rounds are used to light up a battlefield and include flares and photoflash bombs and cartridges.

7.12.1.1. Flares. Flares typically contain magnesium or aluminum as the fuel. Various colors are produced by different metals: red is produced by strontium, green by barium, yellow by sodium, and blue or green by copper. Refer to the metals MC subsection for recommendations for sampling and analysis for the metals found in flares. Color intensifiers that may be included in flares include hexachloroethane, hexachlorobenzene, dechlorane, and polyvinylchloride. Based on the small quantities of intensifiers in the flares and the expectation that these compounds will be expended during use of the flares, no chemical analyses typically are recommended.

7.12.1.2. Photoflash Bombs and Cartridges. Photoflash bombs and cartridges are used to generate lighting at altitude to obtain photographs. Type I photoflash powder used during WWII contained 34% magnesium, 26% aluminum, and 40% potassium perchlorate. Type III, class A photoflash powder used in the 1950s contained 40% aluminum, 30% barium nitrate, and 30% potassium perchlorate. Photoflash powder is very sensitive to shock, friction, and electrostatic discharge. For sites suspected or known to have photoflash bombs or cartridges, refer to the sampling and analysis recommendations for perchlorate discussed above.

7.12.2. Chemical Agent Simulants. Chemical agent simulants are chemicals that closely resemble CAs but are less toxic and, therefore, amenable to training and testing (both field testing and laboratory testing). Common chemical agent simulants include mustard simulants, G agent simulants, VX simulants, and triphosgene (phosgene simulant).

7.12.2.1. Mustard Simulants. Mustard simulants include molasses residuum (MR), asbestine suspension (AS), diethyl adipate, methyl salicylate, and 2-chloroethyl ethyl sulfide (CEES). MR is a concentrate of stillage from fermentation of molasses, treated to prevent further fermentation. It was used for training as early as 1937 (its use has been documented on FUDS) and was used in tests of smoke tanks, thin case bombs, and chemical land mines. It contained cresol as a stabilizing agent. AS is a suspension of finely ground asbestos in water. It may or may not include butyric acid. It was dispersed by spray from aircraft during training exercises. Diethyl adipate was used in decontamination and dissemination studies. Methyl salicylate was used to perform entry/exit tests for shelters. CEES was used in decontamination, detection, contact hazards, and clothing protection studies. Analytical testing of environmental media is not recommended for any of the mustard simulants.

7.12.2.2. G-Agent Simulants. G-agent simulants include the following compounds:

a. Diethyl hydrogen phosphonate – used to study spectroscopy behavior and ionic reactions of G-agents

b. Diethyl malonate – used to simulate viscosity and elastic shear of G-agents and used as GA simulant in CAIS kits (documented use on FUDS)

c. Diethyl p-nitrophenyl phosphate – used to simulate hydrolysis mechanisms

d. Dimethyl methylphosphonate – used to study vulnerability of military assets, decontamination, and dissemination

e. Dipropylene glycol monomethyl ether – used to activate G-agent monitors and detection instruments due to similar ion mobility characteristics

f. Triethyl phosphate – used to simulate G-agents on painted surfaces for decontamination

g. Trimethyl phosphate – used in decontamination studies

Analytical testing of environmental media is not recommended for any G-agent simulants.

7.12.2.3. VX Simulants. VX simulants include the following compounds:

a. Bis(2-ethylhexyl)(2-ethylhexyl) phosphonate – used in decontamination studies

b. Bis(2-ethylhexyl) phosphonate – used in decontamination studies and spray tank testing

c. Dimethyl hydrogen phosphonate – used in studying spectroscopic behavior and ionic reactions

d. Parathion – used to verify mechanical systems

e. Diethyl phthalate – used in decontamination studies

f. Diethyl pimelate – used in decontamination studies

g. Dimethyl adipate – used in decontamination studies

h. Malathion – used to verify mechanical systems

i. Trioctyl phosphate – used in spray tank testing

Analytical testing of environmental media is not recommended for any VX simulants.

7.12.2.4. Triphosgene. Triphosgene is a phosgene simulant used in CAIS kits. It has been documented as having been present at FUDS. No sampling or analysis is recommended for triphosgene.

7.13. Polynuclear Aromatic Hydrocarbons.

7.13.1. Training activities can result in site contamination by substances that are not classified as MC because they do not originate from UXO, DMM, or other military munitions or the breakdown of those munitions. Whether or not such substances pose an unacceptable risk needs to be answered or otherwise addressed in order to close out a site. Also, the MRS Prioritization Protocol (MRSPP) scoring protocol assesses MC as well as any incidental non-munitions-related contaminants. Two examples of such substances are PAHs in clay targets at skeet ranges and various decontamination materials, such as DANC, used to decontaminate soil contaminated with certain types of blister agents (sampling and analysis considerations for DANC are discussed in Section 7.8.7).

7.13.2. PAHs (from coal tar pitch), some of which are carcinogenic (e.g., benzo(a)pyrene), make up approximately 30% of clay pigeons used as skeet and trap range targets, especially during the 1940s. PAHs from skeet targets are not highly mobile; therefore, soil typically is the primary medium of concern. There are many potential non-DoD ambient sources of PAHs that should be considered in an investigation, including roadways, runoff from surface sealant, and fuel burning byproducts.

7.13.3. If incremental sampling methodology (discussed in Chapter 8) is used at a site, and PAHs are analytes of interest, then during the TPP process, the PDT should consider soil sample handling procedures to be followed by the laboratory. For instance, heat generated during prolonged or aggressive grinding using a ball mill or puck mill could cause analyte loss, particularly of the lighter molecular weight compounds. Additional considerations for PAH sample preparation for IS are discussed in Chapter 8.

7.13.4. Field analytical methods for PAHs include USEPA 4035, which is a soil screening approach based on immunoassay, and USEPA 4425, which uses a reporter gene on a human cell line.

7.13.5. There are several fixed laboratory analytical methods for PAHs. USEPA 8310 and USEPA 8270 SIM are recommended. USEPA 8100 and USEPA 8275A are also published methods.

## 7.14. Identifying Munitions Constituents in Munitions.

7.14.1. There are a variety of resources that can be used that provide information on the types of materials that make up various munitions types, including Common Operations Reports, Technical Manuals (TMs), other historical documentation, and munitions-related databases, including the Munition Items Disposition Action System (MIDAS) and the MVS Munitions Database. Accessing these information sources provides insight into what MC might be present at a site. Because some resources may have restricted use or be for official use only, it is important to consult with the appropriate USACE office of counsel if you have questions about the documents.

7.14.2. There are three types of Common Operations Reports that provide FUDS-era information: Installation Type reports, Range Operations reports, and Support Services reports.

7.14.2.1. The Range Operations reports contain information that is useful in developing a CSM for FUDS-era ranges. The Range Operations reports have the following general structure:

a. Executive Summary

b. Introduction

c. Description of Operations

d. Authorized Munitions, Materials Use, and Storage Practices

e. Disposal Management Practices

f. Notable Variations from Typical Operations

g. Closure and Range Clearance Procedures

h. Appendix A – Applicable Manuals and Directives

i. Appendix B – Weapons and Ammunition Data Sheets

j. Appendix C – Glossary of Terms and Acronyms

k. Appendix D – Munitions Constituents Table

l. Appendix E – Propellants, Explosives and Pyrotechnics

7.14.2.2. Range Operations reports are available for 23 different range types:

a. RO-01 Small Arms Range

b. RO-02 Multiple Weapons Type Ranges

c. RO-03 Field Artillery Range

d. RO-04 Mortar Range

e. RO-05 Shoulder-Launched Small Rocket Range

f. RO-06 Medium Caliber Rocket

g. RO-07 Heavy Rocket and Guided Missile

h. RO-08 Recoilless Rifle Range

i. RO-09 Davy Crockett Common Range

j. RO-10 Tank Range

k. RO-11 Anti-Tank Gun

l. RO-12 Antitank Guided Missile

m. RO-13 Anti-Aircraft Artillery Range

n. RO-14 Hand and Rifle Grenade Range

o. RO-15 40 mm Grenade Launcher Range

p. RO-16 Flame Thrower Range

q. RO-17 Mine, Booby-trap, and Demolition Area

r. RO-18 Chemical Warfare Training Area

s. RO-19 Helicopter Weapons

t. RO-20 Fixed Wing Air-to-Air Weapons Range

u. RO-21 Fixed Wing Air-to-Ground

v. RO-23 Coast Artillery Range

w. RO-24 OB/OD Range

Note: RO-22 was to be for Maneuver Ranges; however, the material was covered in the other Range Operations reports.

7.14.2.3. Some of the Common Operations Reports are located on the Army's Engineering Knowledge Online (EKO) Web site, and others are available on the FUDS Records Management Database under nonproject documents. Some Common Operations Reports may have restricted use status; contact the EM CX for assistance and access to the Common Operations Reports.

7.14.3. Technical Manuals are designated as "TM" by the Army but also are available from the other services, which have their own designations. In addition, MC-related information also may be obtained from other manuals produced by the Army. The term "Technical Manual" as used herein refers to any service's manuals or other available historical documentation that the PDT may reference for information on MC. Starting with the War Department era, each service had its own manuals (although some were authored jointly). These manuals were updated whenever doctrine, materiel, or other key factors required updates. Electronic copies of these manuals are available from the Internet in some cases; however, frequently they are poor reproductions and may not be searchable electronically. Some of the manuals are available on the FUDS Records Management Database. More recent manuals may have distribution restrictions. The ordnance/explosives safety community is typically a good source of technical manuals, and the PDT is advised to consult with ordnance and explosive safety personnel to assist with nomenclature.

7.14.4. Munitions-related databases include the MVS Munitions Database and the MIDAS database.

7.14.4.1. The MVS database is primarily focused on FUDS-era ranges and munitions and may be accessed at the following Web site: https://mvs-fs18-

ecprr.mvs.ds.usace.army.mil/munitionsdb/. Access to the MVS database is restricted to USACE personnel and contractors behind the firewall.

7.14.4.2. MIDAS provides comprehensive information on the components that make up various munitions, and reports may be requested at varying levels of detail. The database allows searches by National Stock Number (NSN), DoD Identification Code (DoDIC), Family, Nomenclature, and Drawing Number (the NSN, DoDIC, and Nomenclature searches are most commonly used by PDTs). MIDAS may be accessed at the following Web site: https://midas.dac.army.mil/). Access to MIDAS requires registration for the database and a CAC. Contractors that require access should coordinate with their DoD point of contact to acquire a CAC and a sponsored account.

7.14.5. Table 7-20 shows some of the advantages and disadvantages of these MC identification tools.

Table 7-20: MC Identification Tools – Advantages and Disadvantages

| MC in UXO Tool | Advantages | Disadvantages |
|---|---|---|
| Common Operations Reports | • Focuses on FUDS-era ranges and munitions | • No information on metals MC<br>• Generally, no information on amount of MC |
| TMs | • Specific to each munition<br>• Can have period-of-use information | • May not be readily available<br>• Can be difficult to find the required information (not indexed and/or hard-copy only) |
| MVS database | • Focus is on FUDS-era ranges/munitions<br>• Database format, so searchable | • No information on metals MC<br>• Searching for MC not always intuitive (entries are not always entered based on chemical nomenclature) |
| MIDAS | • Comprehensive – both energetic and metals by component of the munition item<br>• Has some FUDS-era munitions<br>• Includes modern-era munitions<br>• Database format, so searchable | • Period of use not available<br>• Obsolete munitions may not be covered.<br>• Searching can be difficult without experience. |

# CHAPTER 8

## Site Characterization Strategies

8.1. Site Characterization Overview, Goals, and Objectives.

8.1.1. Introduction. Characterization strategies may be performed during various project phases, including the SI, RI, EE/CA, RmD, and RD. However, the amount of data, the performance metrics, and/or the technologies required to collect the required site characterization data may vary. This chapter discusses site characterization approaches for RIs, and Chapters 9 and 10 present more details on site characterization for MEC and MC, respectively.

8.1.2. Scope of Chapter. Although the generalized site characterization approach presented within this chapter is focused on RIs, much of the guidance contained within this chapter can be extended to any site characterization phase of the MMRP. The PDT should develop the site characterization technical approach and project quality objectives (PQOs) with the involvement of project stakeholders through the use of the TPP process (see Chapter 2 and EM 200-1-2 for more details on the TPP process). It should be noted that the general site characterization goals for land and marine MRSs are equivalent for a particular MR project phase; however, the PQOs and the methods and technologies required to meet the PQOs may be significantly different.

8.1.3. SI Objectives. The fundamental objectives of an SI are to eliminate from further consideration MEC or MC releases that pose no significant threat to public health or the environment and to determine the potential need for removal action (USEPA, 1992). The SI phase is not intended to collect enough data to determine the nature and extent of the contamination but is focused on determining the presence or absence of contamination at a site.

8.1.4. RI Objectives. The objectives of an RI are to characterize an MRS by determining the nature and extent of MEC and/or MC at the MRS, to determine the potential interactions between receptors and MEC and MC for the site-specific land use, and to complete the BRA and MEC HA. The RI objective is to gather sufficient information to determine the nature and extent of MEC and/or MC contamination. This objective does not require the unobtainable goal of removing all uncertainty but rather to gather information sufficient to support an informed risk management decision regarding which remedy appears to be most appropriate for a given site (USEPA, 1988). MMRP RIs should be MRS-specific and assess all munitions-related hazards (i.e., MEC and MC) across the entire MRS. MRS site characterization during the RI should determine the nature and extent of MEC and MC by obtaining the amount, type, and quality of data to:

a. bound and characterize the MEC and MC at an MRS;

b. enable comparison of remedial alternatives;

c. determine areas that are not impacted by concentrated munitions use; and

d. establish baseline risks to human health and the environment and baseline explosive safety hazards.

8.1.4.1. RIs may use a multitude of data. These data may be existing data collected during previous investigations and cleanups. Typical data used in the determination of the nature and extent of MEC and MC include, but are not limited to:

a. PA and/or other historical records analysis (e.g., ASR);

b. previous investigations (e.g., SI) or removal actions (e.g., TCRA, NTCRA);

c. historical photographic analysis, including aerial photographic analysis;

d. on-the-ground reconnaissance;

e. geophysical investigations;

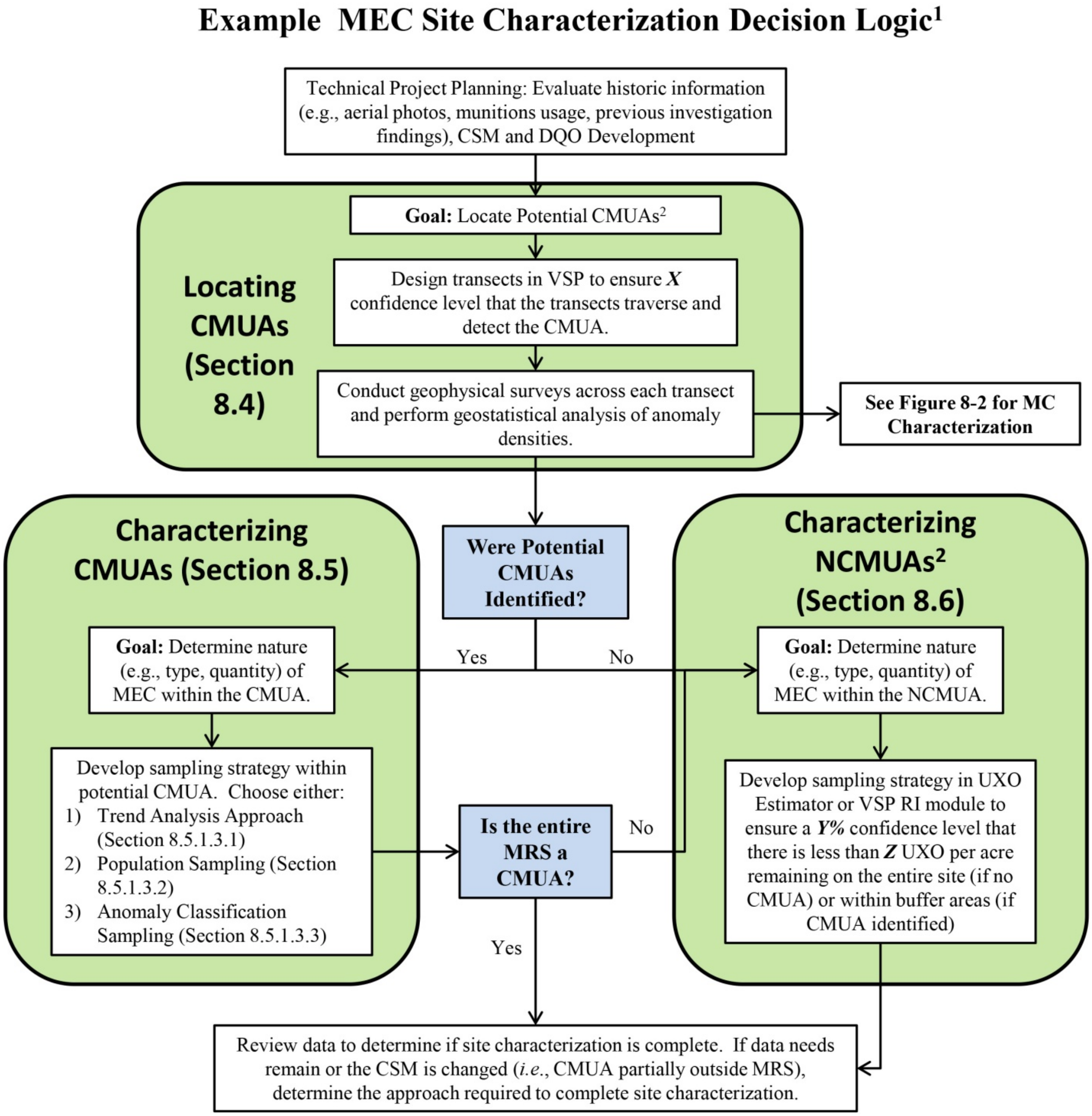
f. excavation and identified geophysical anomalies; and

g. MC sampling.

8.1.4.2. Figure 8-1 shows an example of an RI site characterization decision logic diagram for MEC site characterization; Figures 8-2 and 8-3 show example RI site characterization decision logic diagrams for CMUAs and NCMUAs, respectively. CMUAs are MRSs or areas within MRSs where there is a high likelihood of finding MEC and that have a high amount of MD within them as a result of historical munitions use and fragmentation. CMUAs are most commonly target areas on ranges; however, they also include explosion sites, open burn / open detonation areas, and potentially even disposal sites where munitions have been disposed of over a relatively large area (i.e., not small, isolated burial pits). NCMUAs are areas within an MRS where there is a low amount of MD and UXO due to limited historical munitions use and fragmentation. NCMUAs may be entire MRSs (e.g., training or maneuver areas) or they may be a portion of an MRS outside of a CMUA (e.g., buffer areas). See Sections 8.4, 8.5, and 8.6 for further guidance on locations of CMUAs, characterizing CMUAs, and characterizing NCMUAs, respectively. Figures 8-4a and 8-4b show an example RI site characterization decision logic diagram for SARs. Sections 8.2 through 8.8 provide additional guidance on each of the elements contained within these figures.

8.1.5. <u>EE/CA Objectives</u>. Historically, site characterization under the MMRP was performed using the EE/CA process, not under an RI. EE/CAs typically were performed property-wide (i.e., EE/CAs were not confined to just MRAs and MRSs) and included limited to no MC sampling. Removal actions, including EE/CAs, according to CERCLA and the NCP, are limited actions that are only authorized as an exception to the normal remedial process to address urgent or immediate risks to human health and the environment. EE/CAs currently are required for NTCRAs, including:

a. assessing the MEC hazards at a site and how site characteristics (e.g., erosion) and land use affect these hazards;




**Note:**
1 – Note that this is just one example of the site characterization decision logic that a PDT may use. It is not intended to represent guidance for all sites, nor should it be applied to all sites. The PDT must determine the appropriate site characterization approach given site-specific information including, but not limited to: site usage, characterization goals, previous investigation results, land use, ability of technology to access the site, etc. Site characterization strategies also need to address preliminary RAOs.
2 – CMUA= Concentrated Munitions Use Area; NCMUA = Non-Concentrated Munitions Use Area. See Sections 8.4-8.6 for further details.

Figure 8-1: MEC Site Characterization Decision Logic

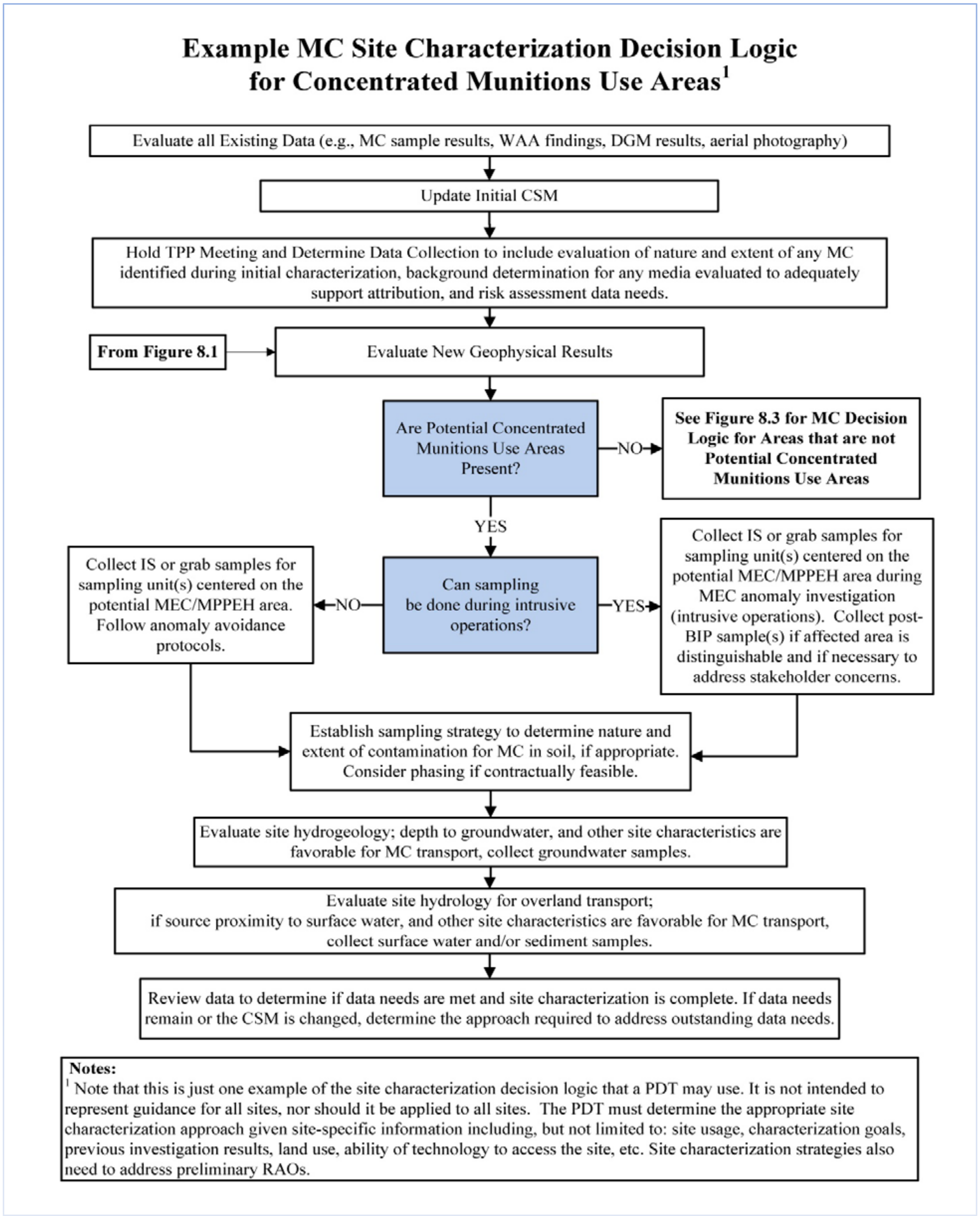
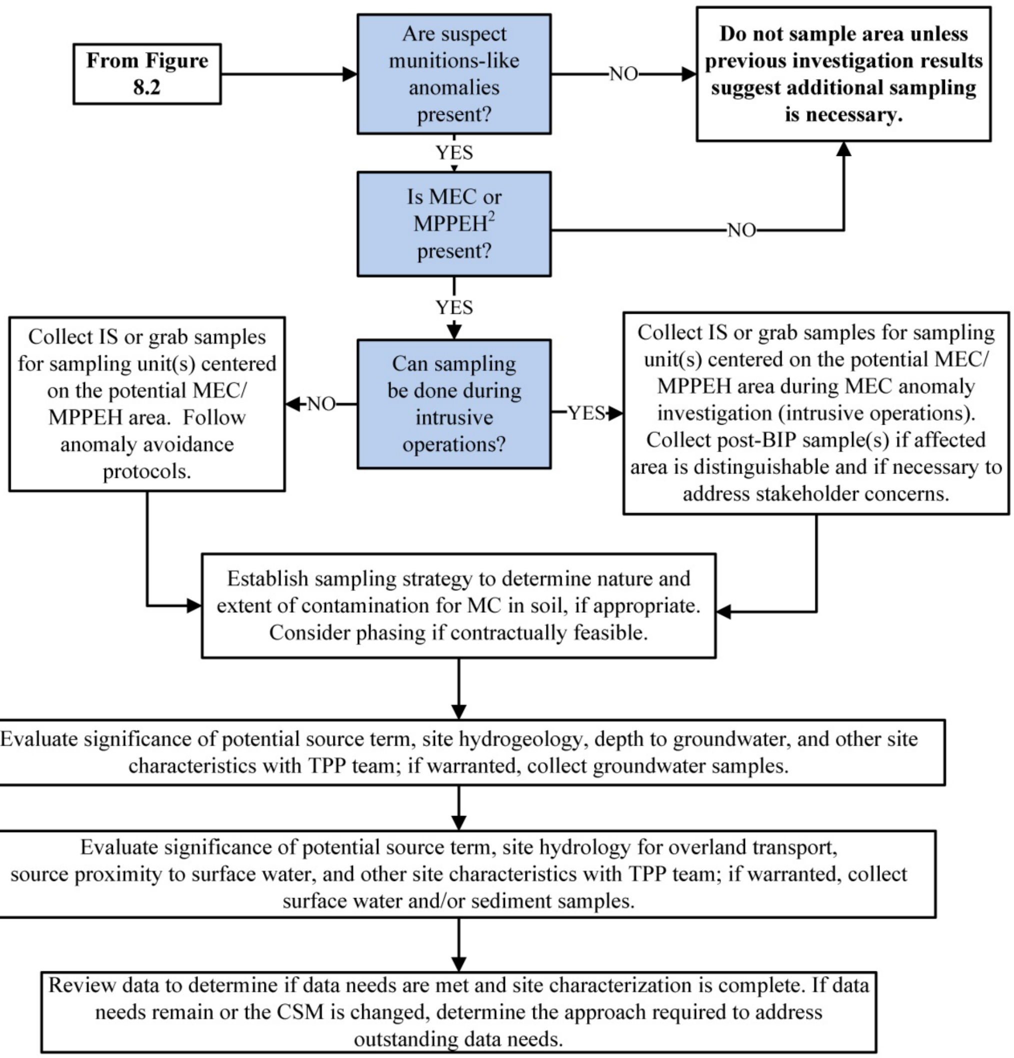



Figure 8-2: Example MC Site Characterization Decision Logic for CMUAs

**Example MC Site Characterization Decision Logic for Areas Without Concentrated Munitions Use[1]**

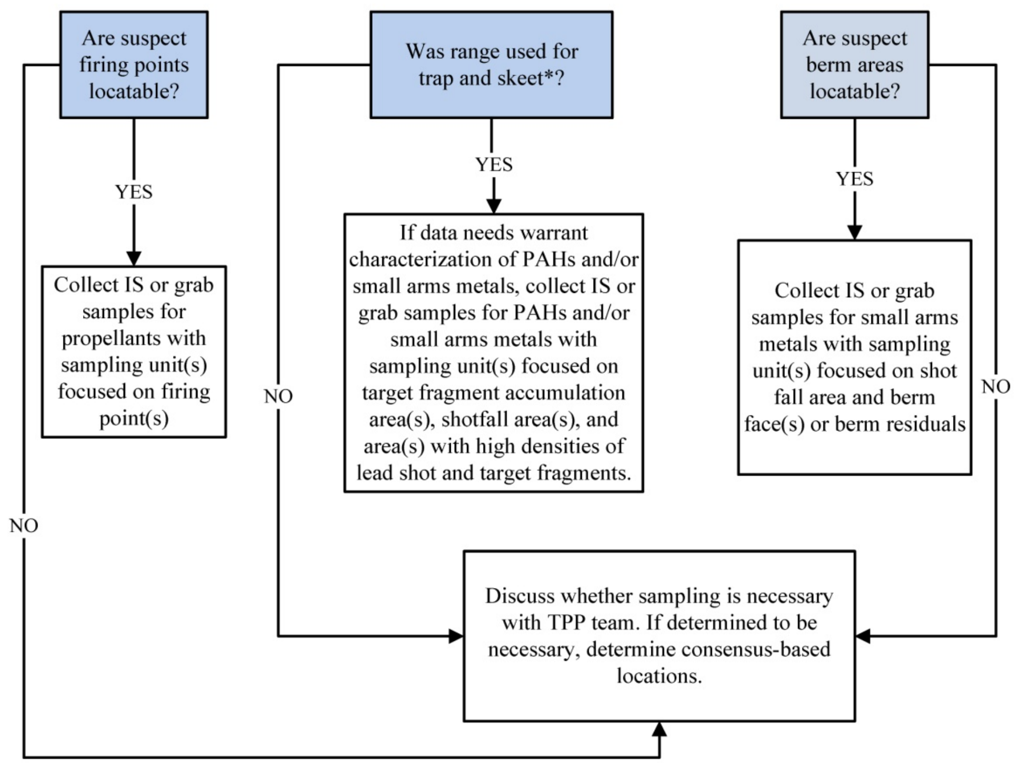



**Notes:**
[1] Note that this is just one example of the site characterization decision logic that a PDT may use. It is not intended to represent guidance for all sites, nor should it be applied to all sites. The PDT must determine the appropriate site characterization approach given site-specific information including, but not limited to: site usage, characterization goals, previous investigation results, land use, ability of technology to access the site, etc. Site characterization strategies also need to address preliminary RAOs.
[2] MPPEH (other than small arms ammunition)

Figure 8-3: Example MC Site Characterization Decision Logic for NCMUAs

## Example MC Site Characterization Decision Logic for Small Arms Ranges[1]

### Part 1: Initial Characterization of Presence or Absence[2]




* Eligibility of skeet ranges may vary by program. Consult with program management for guidance.

**Notes:**
[1] Note that this is just one example of the site characterization decision logic that a PDT may use. It is not intended to represent guidance for all sites, nor should it be applied to all sites. The PDT must determine the appropriate site characterization approach given site-specific information including, but not limited to: site usage, characterization goals, previous investigation results, land use, ability of technology to access the site, etc. Site characterization strategies also need to address preliminary RAOs.
[2] Initial site characterization should also evaluate other media as described on Figure 8-4b, to the level appropriate for data needs (presence or absence of contamination vs. nature and extent of contamination).

Figure 8-4: Example MC Site Characterization Decision Logic for SARs

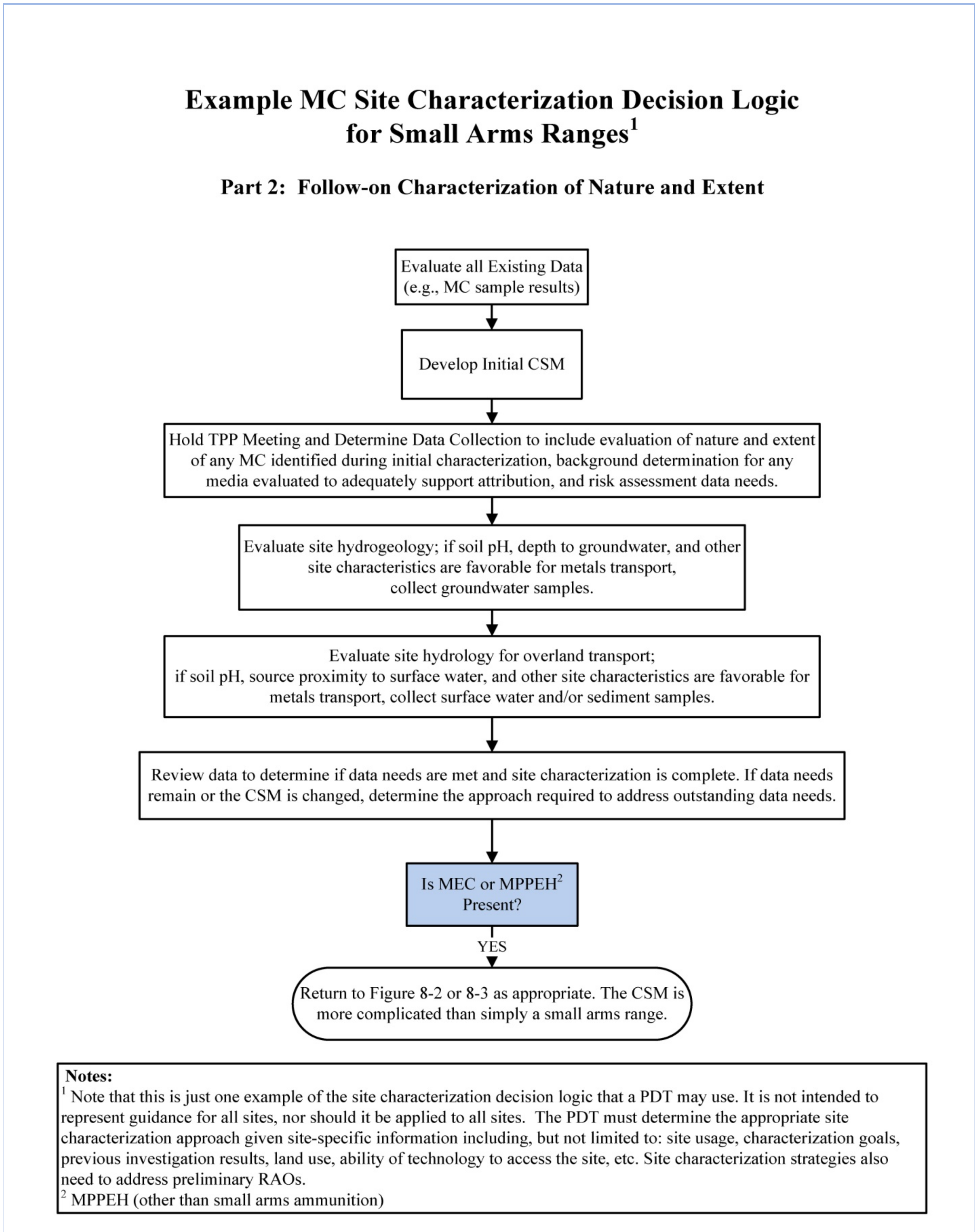



Figure 8-4: Example MC Site Characterization Decision Logic for SARs (continued)

b. performing limited sampling of the site to characterize the source, nature, and extent of UXO and DMM;

c. identifying the removal action objectives;

d. identifying and comparing removal action alternatives;

e. recommending the removal action; and describing the interim monitoring program before the permanent remedy can be established.

8.1.5.1. Current practice is to perform an RI to characterize the nature and extent of MEC and MC at an MRS; however, EE/CAs may still be used for the following purposes:

a. NTCRAs (IAW the requirements of 40 CFR 300.415(b)(4)(i))

b. Characterizing a localized area

c. To alleviate an immediate hazard (i.e., sites with known MEC or MC where receptors have access)

d. Short-term action

8.1.6. RD and RmD Objectives. Following the selection of a particular remedy for a site, the RD or RmD is used to develop the detailed designs, plans, specifications, and bid documents as necessary to implement the selected RA or removal action, respectively (USEPA, 1995). In order to develop these documents, additional site characterization may be required to collect additional information to adequately complete the RD or RmD, as well as to scope the RA or removal action.

8.2. Site Characterization Planning Considerations.

8.2.1. MRS Boundary Verification. The first component of properly planning site characterization activities is for the PDT to identify the appropriate MRS in the database of record, which may be FUDSMIS or AEDB-R (to be replaced by HQAES in the future). Maps showing the currently submitted MRS boundaries also can be found in FUDSMIS for FUDS sites and in the Annual Report to Congress for all DoD MRSs. It is critical that the PDT determines the appropriate boundary and acreage for an MRS prior to planning and conducting site characterization to ensure that site characterization activities characterize the entire MRS in the database of record. Reliance on GIS files from previous investigations and/or site reports may not identically match the MRS boundary in the database of record and may, in a worst-case scenario, be in an incorrect geographic location. Failure to identify the appropriate boundary of record prior to beginning the project may lead to incomplete site characterization and result in having to remobilize to the MRS to complete the site characterization activities.

8.2.2. Geophysical Survey Types. Different geophysical survey types can be used to locate and characterize UXO and DMM within MRSs. The decisions about the types and amounts of geophysical investigation are site specific, may depend on the MMRP phase of the project, and should incorporate the CSM and project DQOs established through the TPP process.

Basically, there are two choices: investigate the entire MRS or sample a representative portion of the MRS (and subareas such as the CMUA) and infer the results across the whole MRS, the CMUA, or the NCMUA. On relatively small sites, it can be efficient in terms of cost, schedule, and environmental impact to geophysically map the entire area. On larger MRSs, statistically designed geophysical approaches are an appropriate method where a small geophysical sample can be interpolated between sampling locations. Two examples of statistically designed approaches are transects spaced evenly across a site to identify CMUAs and grids placed randomly across a site to identify an upper limit on the potential amount of MEC within a CMUA or an NCMUA. Statistically designed surveying methods are designed in VSP and UXO Estimator and are discussed further in Section 8.3. In many cases, historical information will provide general locations and usages of ranges and other training areas, and these historical locations can be used to locate geophysical sampling. MEC site characterization geophysical survey types include meandering path surveys, transect surveys, and grid surveys. Each of these geophysical survey techniques is discussed in greater detail below.

8.2.2.1. Meandering Path Surveying. Meandering path surveys often are used in the SI phase to identify the potential presence/absence of MEC at a site, and the identified anomalies typically are not excavated. Meandering path surveying is a process where a geophysical instrument is integrated with a navigation instrument, usually GPS or DGPS, which links positional data with the geophysical readings. Meandering path surveys need to be designed to meet specific project DQOs that will be input into decisions to support SI objectives. Afterward, the geophysical data are analyzed and anomalies are located and then may be excavated and evaluated, if required. If the purpose of the meandering path survey is to estimate the number of anomalies in a given area, then the method can offer large cost savings on project properties with difficult vegetation and terrain since vegetation removal costs are virtually eliminated and surveying costs are reduced greatly. However, if the sampling plan requires that the anomalies be reacquired and intrusively investigated, then the method becomes much more expensive because of poor positional accuracy that often is associated with this method. The poor positional accuracy can significantly increase the cost of the reacquisition task of the project. An example of meandering path surveying is shown in Figure 8-5.

8.2.2.2. Transects. Geophysical investigation transects are one approach used to characterize MRSs. Transect data generally are tied directly to project DQOs stemming from VSP planning in the TPP process and to decision rules developed to bound and characterize CMUAs. Geophysical transect DQOs may be defined to ensure a specific confidence level that the transect survey will traverse and detect target areas of a certain size; to determine the boundaries of CMUAs to a specific accuracy; to locate CMUAs of a given size to a certain confidence level; to map anomaly density and distribution across an MRS based on geophysical transect results; and/or to perform post-anomaly verification sampling to evaluate potential residual UXO left on an MRS after a removal action has occurred.

8.2.2.2.1. VSP, which is discussed further in Section 8.3.1, is a common software program used to generate geophysical transects. The orientation of transects relative to a potential CMUA or site should facilitate ease of surveying given topology and maximize the potential for CMUA traversal (i.e., transects were designed to ensure traversal and detection of the smaller axis of an ellipsoidal target area). DGM and mag-and-dig transects can be designed

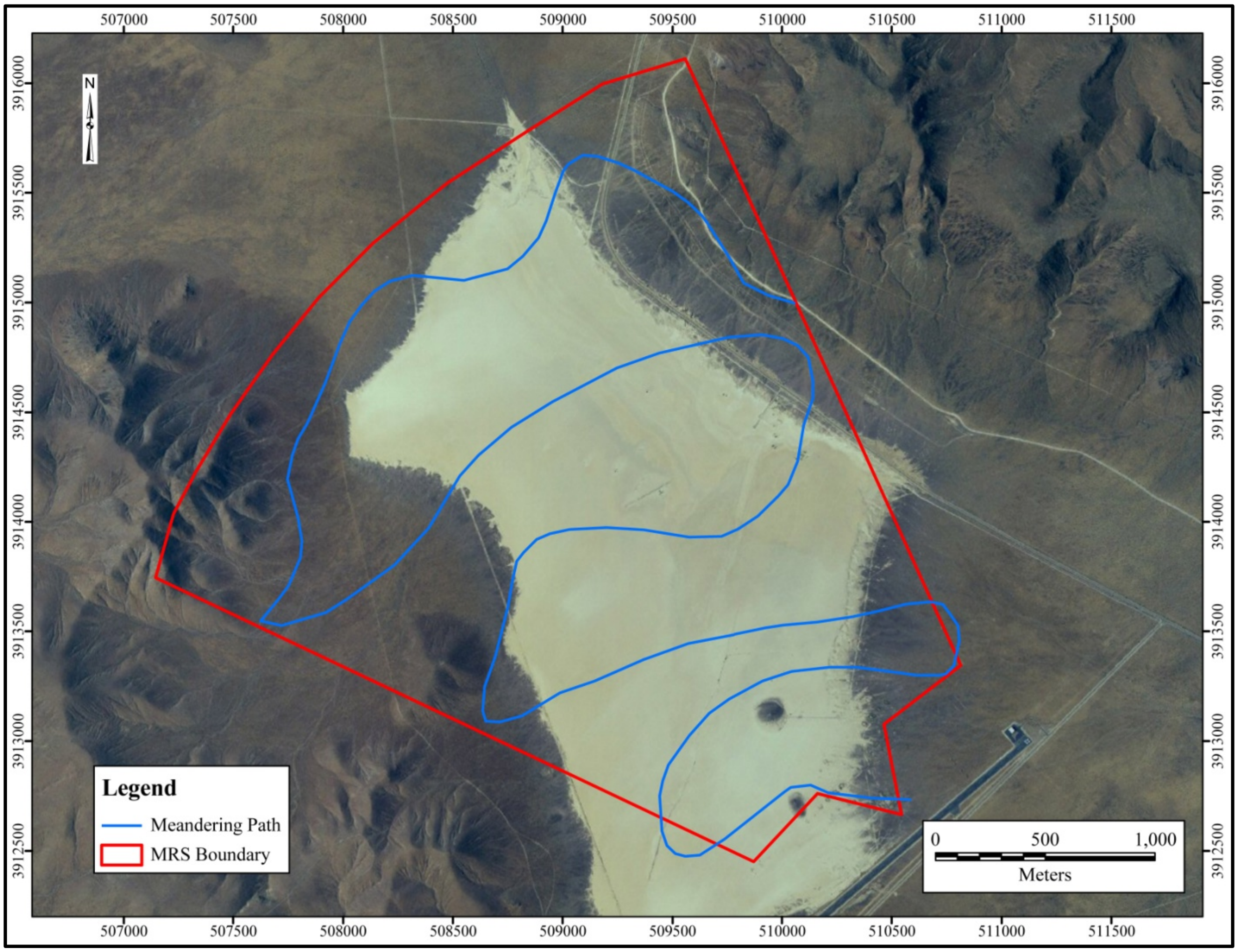



Figure 8-5: Meandering Path Surveying Within an MRS

in the same manner using VSP. Transect surveys can be implemented as either analog or digital geophysical surveys. For both types of transects, the transects follow a semifixed path with defined start and end points. The transects are placed parallel to each other to meet statistical confidence levels needed to ensure traversing and detecting potential CMUAs.

8.2.2.2.2. Figure 8-6 shows an example of the data analysis associated with ground-based geophysical transect surveys to identify CMUAs. In this example, the project DQOs are to traverse and detect a CMUA of a given size to a specific confidence. The geophysicist used VSP to determine the transect spacing required to meet this DQO. The upper left image shows traversed geophysical transects (green lines) based on the VSP calculations and the geophysical anomalies (blue circles) identified during the survey. The geophysicist then evaluated the geophysical transect and anomaly data in VSP to locate areas with elevated anomaly density above the background anomaly density and to map the anomaly density across the MRS. The lower left corner shows areas with elevated anomaly densities (red squares) above the background anomaly density. The right side of the figure shows the calculated anomaly density across the entire MRS. Red-shaded areas are high anomaly density areas that potentially may be

CMUAs. Tools for developing geophysical transect surveys and evaluating geophysical transect data are contained within VSP and are discussed further in Section 8.3.1 of this manual.

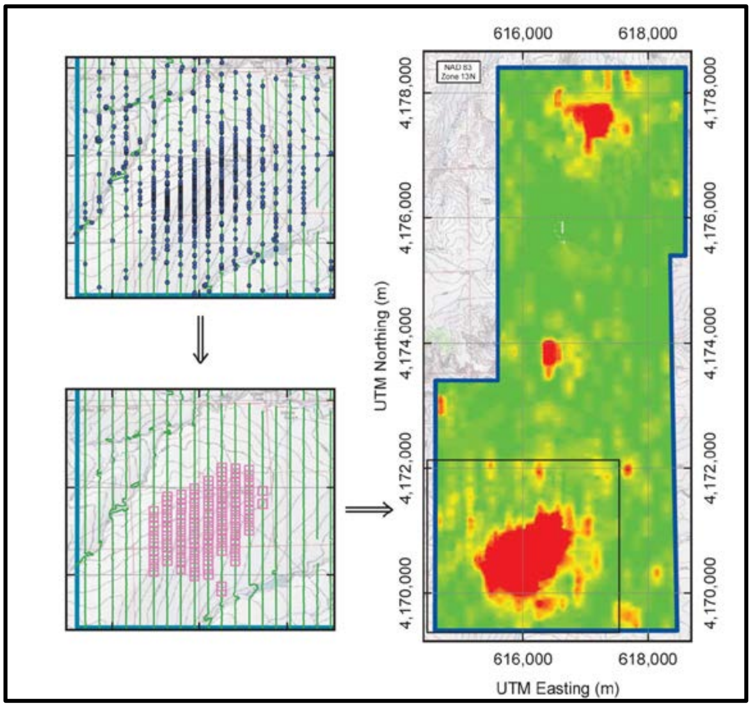



Figure 8-6: Example of Using Ground Based Transects to Locate CMUAs in an MRS (from Nelson et al., 2008)

8.2.2.3. Grid Surveying. Geophysical grid surveys can be placed in random or biased locations during site characterization. Random grid surveys typically are designed using UXO Estimator to determine the upper limit on the UXO density within an NCMUA to a statistical confidence level (see Section 8.3.1 for further details on UXO Estimator). The PDT may place fixed, or biased, grids at firing points to identify potential DMM or burial points or within CMUAs to characterize the amount and type of MEC impact. Figure 8-7 shows an example of both random and biased grid sampling within an MRS.

8.2.3. Geophysical Site Characterization Planning Considerations.

8.2.3.1. Characterization Planning. This subsection first explains how project needs and project objectives are developed and then describes the various elements to be included in the project UFP-QAPP to document and explain the PDT's decisions in developing the characterization strategy. This subsection also provides detailed considerations for such planning elements as survey coverage, geophysical system accessibility, UXO characteristics, terrain and vegetation characteristics, and cultural features. The contents of this chapter assume site characterization is designed in coordination with the needs and objectives of the MRS CSM. It should be noted that site characterization data needs do not necessarily equate to remedial design data needs. For example, a data gap for a site with an anticipated RA within a target area may include not knowing an accurate number of anomalies or an approximate number of UXO present within the target area; however, RI data may suffice to determine the nature and extent of the UXO within the target area such that cost estimates for an RA may be estimated to a +50%/-30% margin.

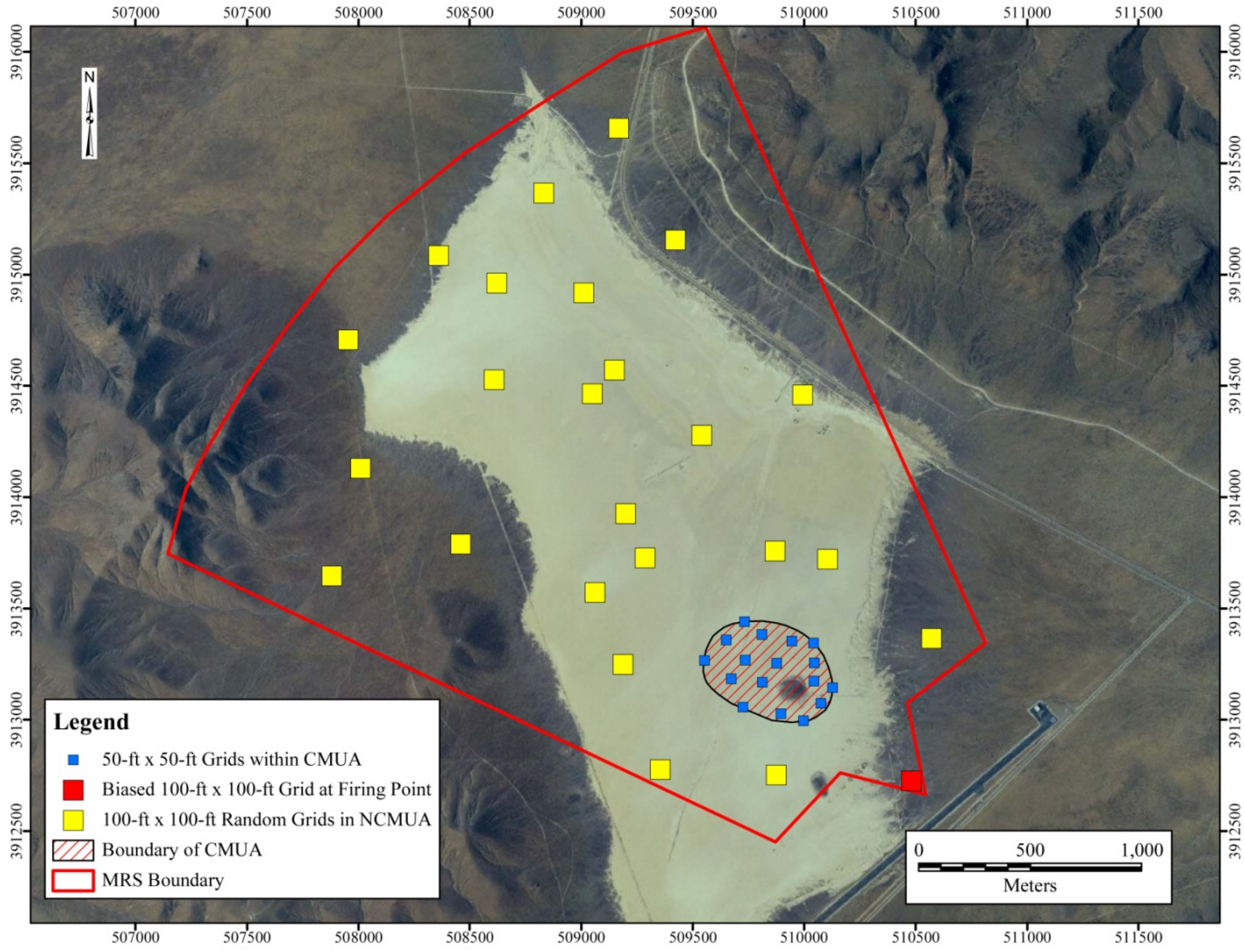



Figure 8-7:  Grid Surveying Within an MRS.
In this example, grids were placed randomly in areas outside the potential impact area (as defined from a previous investigation phase), one biased grid was placed at the firing point, and several biased grids were placed within an impact area to determine the MEC density.

8.2.3.2.  Define Project Needs and Objectives.  This subsection discusses the PDT's role in developing specific geophysical data needs and objectives to characterize an MRS.  Topics generally will be limited to statements describing strategies to characterize CMUAs or NCMUAs.  The PDT will state the purpose of each planned survey type, how much surveying needs is required in each area, and what data and information are needed.  This subsection also explains the need for all PDT data users to understand the reasoning in how geophysical systems and geophysical data will be used and how it will factor in subsequent site-characterization tasks such as HA and RA / removal action cost estimating.  Most MEC characterization goals and decisions are based on geophysical investigations.  PDT input in the design and implementation of geophysical fieldwork is strongly recommended.

8.2.3.3. Tailoring. Key elements of the characterization objectives must be specified before undertaking geophysical planning because significant cost savings can be achieved by tailoring the geophysical investigation plan to the characterization needs. The following lists most characterization needs that affect geophysical investigation planning:

8.2.3.3.1. Based on the CSM, what is the smallest semiminor axis or smallest footprint of the potential CMUA likely to be for each MRS?

8.2.3.3.2. What is the required probability of traversing and detecting the smallest footprint CMUA area for each MRS?

8.2.3.3.3. What is the minimum UXO diameter on a project-specific, site-specific, or even range-specific basis?

8.2.3.3.4. What are the accuracy requirements for determining the extent of CMUAs?

8.2.3.3.5. How will the anomaly density be estimated across the site and how accurate will the density estimates be?

8.2.3.3.6. How will UXO and DMM density at the site be determined and how accurate will the density estimates be?

8.2.3.3.7. For a NCMUA, what is the required confidence level that the site has a UXO density less than x UXO/acre?

8.2.3.3.8. For CMUAs, what is the required confidence level in the determination of the total amount of UXO and DMM within the entire CMUA?

8.2.3.3.9. How critical is it that each anomaly be positively resolved?

- The HA requires each anomaly detected be positively resolved.
- The HA requires each anomaly having MEC characteristics (i.e., TOI) be positively resolved.
- Each anomaly must be positively resolved in each production unit (e.g., grid, transect) until the first UXO is recovered.
- The HA requires certain percentages of each group/cluster/class of anomalies be positively resolved.
- Transect anomalies will not be resolved. All anomalies in grids must be positively resolved; grid locations will be determined based on transect anomaly densities.

8.2.3.3.10. To meet project DQOs and VSP needs and minimize project cost, what is the closest distance any two transects should have between them? (This distance requires supporting statistical calculations.)

8.2.3.3.11. To meet project DQOs and VSP needs, what is the greatest distance any two transects should have between them? (This distance requires supporting statistical calculations.)

8.2.3.3.12. To maximize field efficiency and minimize project cost, what are the minimum and maximum grid sizes that will support both the characterization needs and project budget constraints?

8.2.3.3.13. How accurate must grid centroids and/or transect control points be reported?

- Grid centroids and/or transect control points must be reported to a high-order accuracy.

- Grid centroids and/or transect control points can be reported to a low-order accuracy; distances between grid corners and/or transect control points need to be known to a higher degree of accuracy.

8.2.3.3.14. Do decisions require all detected anomalies to be dug or will a subset of anomalies provide sufficient characterization data? (i.e., Can anomaly classification be used?)

- All anomalies meeting anomaly selection criteria must be dug.

- Anomaly dig lists will be developed and various percentages of each group/cluster/class of anomalies, as defined by the geophysicist, must be dug.

8.2.3.3.15. Do total numbers of anomalies need to be reported? If yes, will “binning” anomaly counts according to geophysical characteristics be needed?

- All detected anomalies must be reported.

- All detected anomalies, grouped by category or priority, must be reported.

- Only those anomalies listed on dig sheets need be reported (this is rare).

8.2.3.3.16. Will high-precision position reporting suffice for project needs or will geophysical data require high-accuracy position reporting as well?

- Measurement positions within grids or along transect must be reported with high precisions; high accuracies are not required because reacquisition procedures are not affected by position accuracy.

- Measurement positions within grids or along transect must be reported with high accuracies to support the reacquisition procedures being used.

8.2.3.3.17. Will the project schedule support a multiphase field effort (e.g., transect mapping/anomaly rate calculations followed by biased grid sampling)?

- Yes, a multiphase approach is supported so that digging resources can be tailored to maximize efficiency.

- No, all work must be performed concurrently to minimize disruption to the community.

- No, all required work is defined, and no efficiencies will be gained through a phased approach.

8.2.3.3.18. Will reacquisition procedures be affected by the passage of time after data collection?

- No. Digging will occur soon after data collection, and reacquisition procedures will not be affected.

- No. Digging will occur at some later time, and reacquisition procedures will not require recovery of grid markers and/or transect markers.

- Yes. Digging will occur at some later time, and reacquisition procedures require recovery of low-order accuracy grid markers and/or transect markers.

8.2.3.3.19. What are the vegetation conditions and are there constraints on vegetation removal (cost, habitat, endangered species, etc.)?

- Vegetation removal is constrained and/or costly. The locations and sizes of grids and/or transects needs to be flexible; some characterization objectives may not be met due to these constraints.

- Vegetation removal is not constrained but is costly. The locations and sizes of grids and/or transects needs to be flexible; some characterization objectives may not be met due to these constraints.

8.2.3.3.20. What are the cultural and/or access constraints?

- Cultural and/or access constraints will impede production rates; some characterization objectives may not be met due to these constraints.

- There are no cultural and/or access constraints that will impede production rates and characterization objectives will not be affected.

8.2.4. <u>MC Investigation Planning</u>.

8.2.4.1. <u>Initial MC Investigation Planning</u>. Planning for the MC investigation is closely intertwined with planning for the MEC investigation and follows the same TPP process described above. Site characterization of MC is based on identifying either a source or a release. In either case, the MC must, by definition, be from a military munition. Therefore, it is a recommended practice to focus characterization on areas where these munitions items currently are or historically were located (e.g., target areas) and areas from which munitions items were fired (e.g., SAR firing lines, artillery firing points). In many cases, the locations of MC samples cannot be determined at the outset of a project. Rather, MC sampling locations may be selected based on geophysical results and/or field MEC findings. Therefore, it is important to plan for a phased approach for MC sampling (see Figures 8-2 and 8-3 for example decision logic for MC characterization). As part of the TPP, the PDT must decide what findings will constitute identifying an area as contaminated with MC and what findings will support a determination of "no contamination indicated." Once such a determination is made, all subsequent data collected in that area should be focused to answer more specific questions about the types of MC present, the lateral extents and concentrations of contamination, and the vertical extents and concentrations of contamination.

8.2.4.2. Objectives of Site Characterization. MC site characterization should be performed to meet the DQOs and data needs of the project. MC site characterization typically is performed to achieve the objectives discussed below.

8.2.4.2.1. Determining Presence or Absence of MC Contamination. If MEC are present (or suspected) at a site and the presence of MC in environmental media is unknown, sampling is conducted to determine whether it exists. This type of investigation typically is biased, or non-probabilistic, to look at areas where contamination is suspected to be the worst case (e.g., target areas, firing lines, OB/OD areas, areas with high MEC concentrations). Limited sampling to evaluate the presence or absence of MC contamination should be conducted during the SI phase of an MR project. Determination of presence of MC at a site is not sufficient to make a decision regarding its significance in terms of potential threat to human health and the environment. The potential threat to human and ecological receptors should be determined through a screening-level risk assessment in the SI. See http://www.epa.gov/superfund/cleanup/pasi.htm for SI guidance.

8.2.4.2.2. Defining the Nature and Extent of the MC. If MC contamination is determined to exist, further investigation may be required to determine the nature and extent of the contamination, as well as to define the risk to human health and the environment. This investigation typically would be conducted during the RI/FS phase of an MR project and should support preparation of a BRA and aid in the development of remedial alternatives. For additional information on RI/FS requirements, refer to the following guidance documents: USEPA's Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (Oct 1998); EM 1110-1-502; and the U.S. Army Military Munitions Response Program, Munitions Response RI/FS Guidance (Nov 2009).

8.2.4.2.3. Post-BIP Sampling. This type of sampling may be required on a site-specific basis during site characterization activities to determine if a release has occurred as a result of BIP detonation. If post-BIP samples are collected, specific DQOs should be established during the TPP process to define the specific uses of the data. Recommendations for performing BIP-related sampling are discussed in Section 8.8.7.3.

8.2.4.2.4. Obtaining Data for an RD. In addition to MC concentration and distribution information, data for other parameters may be required to evaluate the feasibility of remedial alternatives during an RI/FS or pre-RD investigation. These data may be collected at any point during site characterization when certain remedial alternatives are determined to be potentially applicable. In many cases, it is useful to collect these data prior to the FS (e.g., during an RI) to aid in remedy evaluation and to more cost-effectively complete the MR project. Examples of data needs for RD of soil include grain size distribution of soil, organic content, and soil pH for treatment of soils that contain MC.

8.2.4.2.5. Long-Term Monitoring. Long-term monitoring (LTM) activities may be required for the MC portion of MR projects following the remedial action operation phase. If MC sampling and analysis is required during the LTM phase, many of the requirements and recommendations discussed in this section also would apply.

8.2.4.3. Site Characterization Phases. MC site characterization should be performed in a phased approach, building on existing site knowledge, previously collected data, and new data as they are collected. As new data are collected, the PDT should continuously evaluate whether the data substantiate the CSM to determine if additional sampling is required to fully characterize the site. Figure 8-2 presents an example of a phased sampling approach for an RI. The phases of MC site characterization include the following:

a. Initial CSM development (see EM 200-1-12)

b. Systematic planning (See Sections 2.2)

c. Evaluation of previous investigation MC sampling results (see Section 2.2)

d. Site stratification (see Section 8.8.1.2)

e. Evaluation of geophysical results (see Chapter 6 and Sections 8.3-8.7)

f. Initial soil sampling to determine presence/absence of MC (see Section 8.8.1)

g. Surface water, sediment, and groundwater sampling to determine presence/absence of MC (see Sections 8.8.2 and 8.8.3)

h. Additional horizontal and vertical sampling to determine the extent of the contamination

i. If applicable and necessary, sampling for additional parameters required to support RD

8.2.4.4. Background Concentrations. Assessment of background concentrations is very important for parameters that may be present naturally (e.g., metals, perchlorate) or that may have non-DoD anthropogenic sources (e.g., PAHs). Recommendations for planning background assessments are provided in Section 8.8.

8.2.4.5. Discovery of HTRW. Planning also should consider the approach to take if, during the investigation, unanticipated discovery of HTRW contamination is found. Generally, a scope of work does not provide for any additional work to address such contamination. In such cases, the PDT needs to either expand the existing scope or plan for a separately scoped activity.

8.2.4.6. Selection of Analytical Methods. An important aspect of MC investigation planning is the selection of analytical methods to detect and measure MC concentrations. Chapter 7 provides a discussion of typical analytical methodologies. The PDT also should establish project-specific requirements for method sensitivity in terms of an LOQ for each analyte and matrix. The LOQ is the lowest concentration value that meets project requirements for reporting quantitative data with known precision and bias for a specific analyte in a specific matrix. Close coordination with the laboratory is required, as detection and quantitation limits are laboratory specific. For additional guidance, the PDT should refer to the DoD Environmental Data Quality Workgroup Fact Sheet: Detection and Quantitation – What Project Managers and Data Users Need to Know (Sep 2009), available at http://www.navylabs.navy.mil/Final%20DQ%20Fact%20Sheet%20091409.pdf.

8.2.4.7. Planning for Chemical Data Quality Control (CDQC). An effective CDQC system must be established that meets the requirements for the chemical measurement DQOs developed for the project. The system must cover chemical measurements pertaining to and required for contractor- and subcontractor-produced chemical data. The contractor must control field screening, sampling, and testing in conjunction with remedial activities to meet all DQOs, minimize the amount of excavated material requiring temporary storage, prevent dilution of contaminated soils with clean soils, and ensure completion of work within the required time.

8.2.4.7.1. ER 200-1-7 is the umbrella USACE document that defines chemical data quality management activities and integrates all of the other USACE guidance on environmental data quality management. Its purpose is to assure that the analytical data meet project DQOs, which are documented along with the required QC criteria in the approved project UFP-QAPP.

8.2.4.7.2. In addition to the QC requirements specified in Chapter 4, the Chemical Quality Control (CQC) Plan must incorporate the qualifications, authority, and responsibilities of all chemical quality management and support personnel. Chemical measurements including sampling and/or chemical parameter measurement are not permitted to begin until after production and acceptance of the CQC Plan and the government's approval of the QAPP. To cover contract-related chemical measurements by the contractor and all subcontractors, the CQC Plan must include the following, as a minimum:

- Qualifications. Qualifications including the names, education, experience, authorities, and decision-making responsibilities of all chemical management and support staff. The CQC Plan must contain a copy of a letter from the project QC manager authorizing a Chemical QC Officer and chemical QC organization staff.

- Authority and Responsibility. A diagram, flow chart, or figure clearly depicting the chemical data quality management and support staff and the authority and responsibility of each for chemical sampling and analysis, procedures for corrective actions, deliverables and submittals, deviations and changes, chemical quality documentation, data validation, minimum data reporting requirements, and DQOs for chemical parameter measurement by the contractor and subcontractors. The contents of this section of the CQC Plan must be included in the applicable "Project Organization" elements of the QAPP.

8.2.4.7.3. The QAPP must be prepared IAW CDQC requirements, the UFP-QAPP Manual, and the relevant sections of Chapter 4. The QAPP must clearly identify the contractor-obtained laboratories. The contractor must furnish copies of the government-approved QAPP to all laboratories and the contractor's field sampling crew. The QAPP must address all levels of the investigation with enough detail to become a document that may be used as an audit guide for field and laboratory work. The contractor must provide the laboratory quality manual and applicable SOPs as an electronic appendix to the QAPP.

8.2.4.7.4. The contractor's CDQC must ensure that a QC program is in place that assures sampling and analytical activities and the resulting chemical parameter measurement data comply with the DQOs and the requirements of the QAPP. The contractor must utilize the three-phase control system, which includes a preparatory, initial, and follow-up phase for each definable feature of the work. The contractor's three-phase chemical data control process must ensure that data reporting requirements are achieved and must be implemented according to the CQC Plan and the QAPP.

8.2.4.7.5. The contactor must propose the analytical laboratories to be used for the primary samples analysis. Laboratory accreditation requirements must be IAW the laboratory performance requirements, below. The contractor may utilize their own laboratory or utilize subcontract laboratories to achieve the primary required sample analyses.

8.2.4.7.5.1. Laboratory Analytical Requirements. The contractor must provide the specified chemical analyses by the contractor's laboratory. The contractor must provide chemical analyses to achieve the project DQO for all parameters specified by the methods. To give USACE programs the greatest flexibility in the execution of its projects, the SW-846 methods generally are the methods employed for the analytical testing of environmental samples. These methods are flexible and must be adapted to individual project-specific requirements. Method performance must be IAW DoD QSM requirements unless variances are specifically approved in the QAPP. The requirement for the laboratory to provide quantitative second column confirmation for explosives per DoD QSM/USEPA 8330 (i.e., five-point calibrations must be performed for each target analyte for the primary and confirmatory columns and quantitative results for each column must be reported) will not be waived. Based upon project requirements, exceptions will be considered for the following co-eluting pairs: 2-Am-DNT/4-Am-DNT; 2-NT/4-NT; and 2,4-DNT/2,6-DNT.

8.2.4.7.5.2. Laboratory Performance. The contractor must provide continued acceptable analytical performance and must establish a procedure to address data deficiencies noted by review and/or QA sample results. The contractor must provide and implement a mechanism for providing analytical labs with the QAPP, for monitoring the lab's performance, and for performing corrective action procedures. The contractor must acquire analytical services with additional acceptable laboratories in the event that a project lab fails to perform acceptably during the project.

8.2.4.8. CSM and Potential MC. A comprehensive CSM must be developed to help identify data gaps and uncertainties, as well as to serve as a communication tool to define site characterization approaches. EM 200-1-12 describes the steps required to develop a CSM.

8.2.4.8.1. A list of potential MC may be developed based on the types of munitions documented historically to have been used at a site, as well as munitions found during the MEC investigation. If the type of munitions used at the site is fairly well defined for the project, then use of a short list of metals, as determined by the metals associated with the munitions list, is recommended. However, use of short lists for explosives analytes is not particularly cost beneficial and is not recommended. Information sources that provide potential MC based on munitions types are discussed in Chapter 7.

8.2.4.8.2. A list of target MC for laboratory analyses is developed based on the fate and transport properties of the MC (see Chapter 7).

8.2.4.9. Sampling Locations. Initial sampling locations may be planned based on the following information:

a. Results from previous investigations, such as PAs, SIs, or other response actions

b. Aerial photography analysis / WAA

c. Geophysical and MEC intrusive investigation results

8.2.5. Required Elements for MC Characterization.

8.2.5.1. An MC investigation process that is capable of effectively identifying MC contamination must employ three fully integrated components, as follows:

8.2.5.1.1. Experienced Personnel. Personnel involved with the MC investigation should be experienced with the theoretical and practical aspects of military munitions chemistry, field sampling, laboratory analyses, and risk assessment. Selecting laboratories and analytical methodologies, determining appropriate screening levels, and preparing screening-level or BRAs require qualified and experienced individuals. A qualified chemist, a qualified geologist, and a qualified risk assessor should participate actively in the management of all MC investigations beginning with the initial planning and formulation of project objectives. A qualified chemist is a person with a minimum of a bachelor's degree in chemistry or a closely related field and at least 5 years of directly related environmental chemistry experience, preferably involving military munitions. The qualified chemist also should be familiar with the DoD QSM and DoD ELAP. A qualified geologist is a person with a minimum of a bachelor's degree in geology or a closely related field and at least 5 years of experience directly related to environmental site characterization, preferably involving military munitions. A qualified risk assessor is a person with a minimum of a bachelor's degree in chemistry, biology, or toxicology (or a closely related field) and at least 5 years of directly related environmental risk assessment experience. Sampling personnel should be trained in appropriate sampling procedures and associated documentation requirements. If field analytical methods are used, personnel executing these methods should have documented training and experience performing the planned methodology.

8.2.5.1.2. Experienced Laboratory. The laboratory used should have experience in handling MC samples. The analytical laboratory should be identified early in the project planning (preferably at the proposal stage). The laboratory must be identified in the UFP-QAPP and hold applicable state certifications to perform the analytical methods required (if available). Laboratories must demonstrate compliance with the latest version of the DoD QSM and be accredited through DoD's ELAP for all project-required analytes. Selection of laboratories also should be made with knowledge of the latest provisions and requirements specified in DoD Instruction 4715.15, Environmental Quality Systems (10 May 2011); ER 200-1-7, Chemical Data Quality Management for Environmental Cleanup; and DoD Policy and Guidelines for Acquisitions Involving Environmental Sampling or Testing (Nov 2007). For a list of current DoD ELAP-accredited labs, see http://www.denix.osd.mil/edqw/Accreditation/AccreditedLabs.cfm. Unless and until the DoD ELAP accredits IS preparation at the Field of Testing level (i.e., based on the analyte group) for analytes without published IS preparation methods, it is strongly recommended that any MMRP project acquisition that is anticipated to incorporate IS require submittal of laboratory preparation SOPs for government chemist review. This review should be completed as part of the proposal review so that if there are weaknesses, significant weaknesses, and/or deficiencies in the approach due to concerns with the laboratory processing, they can be identified during the technical approach rating and considered during the award process. If the award is made despite concerns identified during the government chemist review, the concerns must be addressed prior to the acceptance of the UFP-QAPP. If they cannot be addressed to the satisfaction of the KO, the contractor must find a laboratory that can successfully perform the requirements of the project.

8.2.5.1.2.1. Any laboratory performing chemical analysis must provide a DoD ELAP certificate and supporting documentation to demonstrate the ability to meet project DQOs, including limits of detection (LODs) and LOQs for the selected analytical methods. The determination of qualifications of the laboratory should be at the discretion of the MMDC Project Chemist.

8.2.5.1.2.2. If the laboratory fails to meet project-specific requirements, appropriate corrective actions will be identified, implemented, and monitored for effectiveness. If the laboratory is still deficient in meeting project-specific requirements after implementation of corrective actions, the KO or Contracting Officer's Representative may request use of the laboratory be discontinued and analytical services be procured from another qualified laboratory that can meet the requirements. Samples may not be subcontracted to another laboratory without the approval of the MMDC Technical Lead. The subcontracted laboratory must meet all requirements for the contract laboratory. If a QA laboratory is to be used, the same requirements apply to the QA laboratory as to the primary laboratory.

8.2.5.1.3. Accuracy and Precision of Sample Locations. The personnel performing the MC investigation must have the ability to accurately and precisely identify a sample location in relation to other known points, preferably using a common survey grid and/or datum. Sample locations should be recorded according to the requirements described in Chapter 5.

8.2.5.2. If any of the above three components is lacking, the overall MC characterization process may be unable to meet the project's objectives. Therefore, it is important to carefully plan and integrate all aspects of an MC investigation and not to start fieldwork prematurely.

8.2.6. Sampling and Analysis Considerations.

8.2.6.1. MRS Layout. An understanding of the layout of the MRS, including target areas and firing point locations, as well as the former and/or current munitions usage (i.e., type of munitions, frequency of munitions use, and length of time that munitions were used), is crucial to planning an MC investigation. Sampling should be focused at areas were MC are most likely to be concentrated. Energetics MC typically are found at target areas for medium- and large-caliber munitions (i.e., CMUAs), firing points (propellant residue only), OB/OD areas, hand grenade ranges, and munitions production facilities. Metals MC may be found at any type of MRS, but they tend to be concentrated at SARs (e.g., lead in berms).

8.2.6.2. MEC Depth. If MEC are located on the surface, generally, initial sampling should be surficial (0 to 2 inches). The sample depth that constitutes surface soil should be defined during the TPP, taking into consideration the end use of the data and applicable regulatory criteria for surface soil. Alternate sampling depths would be appropriate in conditions of shifting sands, erosion, etc. If MEC also are found in the subsurface, initial samples also should be collected from subsurface soil near the identified MEC.

8.2.6.3. MEC Item Composition. Analytical requirements for MC should be based on the anticipated MEC composition, if known (see Chapter 7). If unknown, some assumptions may be made regarding typical composition to establish the analytical requirements for MC. In either case, the anticipated MEC, along with fill information, if available, should be tabulated in the project planning documents. The environmental fate and transport properties of the MC composing the MEC should also be noted, if known. Certain types of MC (e.g., certain chemical agents and explosives compounds) degrade fairly quickly in the environment and, thus, are not recommended for analysis (see Chapter 7).

8.2.6.4. Condition of the MEC Item. During the MEC investigation, it is important to categorize the condition of each located munitions item to indicate whether it is an intact round (i.e., UXO or DMM), a cracked case (result of a low-order detonation), or MD. CRREL and ERDC-EL studies have shown that for contemporary medium- and large-caliber munitions that function as designed and for high-order detonations, minimal energetics residue is generated. Low-order detonations result in a higher likelihood of energetics residue. The likelihood of residue remaining from BIPs varies by round type and donor charge; typically mortars are more likely to leave energetic residue and artillery shells are less likely (Pennington et al., Explosive Residues from Low-Order Detonations of Heavy Artillery and Mortar Rounds, Soil and Sediment Contamination: An International Journal, 17:5, 533-546). If a medium- or large-caliber item malfunctioned (i.e., a dud item) and the case is intact in a noncorrosive environment, then there is a low potential for energetic residue. If the intact case is in a corrosive environment, then there is a potential for energetic residue. If the case was cracked (e.g., if it was hit by another round), then there is a higher likelihood of energetics residue.

8.2.6.5. Timing for MC Sample Collection if MEC or MD are Present. A typical MR project (for non-SAR sites) includes digital geophysics, anomaly selection, anomaly reacquisition, and intrusive activities. Because MC characterization depends on understanding the location, composition, and condition of MEC at the site, the determination of where and when to collect samples for MC analysis should be coordinated with the MEC investigation. Planning for initial MC sample locations may be performed concurrently with the selection of MEC anomalies. Finalization of MC sample locations and actual sample collection may be performed concurrently with MEC intrusive activities.

8.2.6.6. Background Conditions. In some locations, either naturally occurring or anthropogenic background concentrations of metals, perchlorate, fuel oil, PAHs, or other compounds (see Chapter 7), unrelated to munitions, may exceed risk-based screening levels or regulatory limits. If an MC investigation includes these parameters and no appropriate background data are available for the project property, background samples should be collected and analyzed. Background values are used as a standard against which site data may be compared and, in many cases, can provide the basis for eliminating MC carried forward as contaminants of concern based on exceedance of screening levels. This is particularly true for background concentrations of metals that exceed ecological screening values. Therefore, the importance of adequate and defensible background determination cannot be overstated. Some available resources for background condition evaluation include the following:

a. Guidance for Environmental Background Concentration Analysis Volume I: Soil (NAVFAC UG-2049-ENV, Apr 2002)
http://web.ead.anl.gov/ecorisk/related/documents/Final_BG_Soil_Guidance.pdf

b. Guidance for Environmental Background Concentration Analysis Volume II: Sediment (NAVFAC UG-2054-ENV, Apr 2003)
http://web.ead.anl.gov/ecorisk/related/documents/Final_BG_Sediment_Guidance.pdf

c. Guidance for Environmental Background Concentration Analysis Volume III: Groundwater (NAVFAC UG-2059-ENV, Apr 2004)
https://portal.navfac.navy.mil/portal/page/portal/navfac/navfac_ww_pp/navfac_nfesc_pp/environmental/erb/gpr/ug-2059-bkgrnd-analysis.pdf

d. Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites (USEPA 540-R-01-003 OSWER 9285.7-41, Sep 2002)
http://www.epa.gov/oswer/riskassessment/pdf/background.pdf

8.2.6.6.1. The use of published regional background data for evaluation of potential MC-related contamination is not recommended.

8.2.6.6.2. Regional values may be used for general reference at the SI stage or as one element in a weight-of-evidence approach, but comparison of site data to regional values should be done only with thorough understanding and explanation of the data behind the published values. Regional studies often include results from stream sediments, bedrock, or soils of various types derived from diverse parent materials without clear distinction. Such studies are not intended to represent conditions at any specific location in the region, and some (e.g., some U.S. Geological Survey [USGS] reports) are prefaced with cautionary statements to that effect. Published regional values should not be relied on as the only background values for decisions at the RI phase. Design and execution of adequate site-specific background investigation should be part of the site characterization scope. Additional discussion of background sampling is included in Sections 8.8.1, 8.8.2, and 8.8.3, which describe sample collection for each environmental medium.

8.2.6.7. Regulatory Requirements. Various state and local requirements and requests for sampling and analysis may exist. These should be considered and addressed during TPP and the development stage of overall project objectives and DQOs.

8.2.6.8. Chemical-Specific Screening Levels, ARARs, and TBCs. Chemical-specific screening levels, ARARs, and TBCs can impact the choices of the appropriate analytical methodology as part of the DQO process. Anticipated criteria should be established during the planning process to ensure proper sampling procedures can be applied; appropriate analytical methodologies can be utilized; meaningful data can be collected; and DQOs can be achieved. These should be documented in planning documents along with the reporting limits / LODs specific to the project laboratory to allow comparison/confirmation that methodology is adequate.

8.2.6.9. Analytical Issues with Energetics. Although laboratories now have the capability to detect energetics MC at very low concentrations, the lowest levels of detection may not be desirable, especially if they are at the limits of the method/instrumentation sensitivity, because precision and bias may not meet project DQOs. For additional guidance, the PDT should refer to the DoD Environmental Data Quality Workgroup Fact Sheet: Detection and Quantitation – What Project Managers and Data Users Need to Know (Sep 2009), available at http://www.navylabs.navy.mil/Final%20DQ%20Fact%20Sheet%20091409.pdf.

8.2.6.10. Site Hydrology and Hydrogeology. If surface water is located on or near the project property and receives runoff from suspected MC source areas, surface water / sediment sampling should be considered. If significant releases of MC are believed to have occurred and there is a complete source to groundwater pathway, groundwater sampling should be considered. The decision to sample groundwater should be made based on depth to groundwater and its susceptibility to contamination from surface releases based on site geology (e.g., soil type, karst), climate, potential receptors, the magnitude of the suspected MC release, and the physical and chemical properties of MC suspected at the site (e.g., perchlorate).

8.2.6.11. MC Sampling Resources. Other resources are available that may provide information to assist project teams. In instances where these resources conflict with this or other formal DoD or service guidance, the formal guidance should be followed. These resources are considered related (non-essential) and are not required. It is recommended that PDT members familiarize themselves with the available information to make salient technical recommendations specific to their project DQOs, particularly in areas where the science is evolving. They include (but are not limited to) the following:

a. USEPA Federal Facilities Forum Issue Paper, “Site Characterization for Munitions Constituents”, USEPA-505-S-11-001, Jan 2012. http://www.epa.gov/fedfac/pdf/site_characterization_for_munitions_constituents.pdf

b. Incremental Sampling Methodology. ISM-1. Washington, D.C.: Interstate Technology & Regulatory Council, Incremental Sampling Methodology Team, Feb 2012. http://itrcweb.org/ism-1/

c. ERDC TR-12-1, "Evaluation of Sampling and Sample Preparation Modifications for Soil Containing Metallic Residues," Jan 2012. http://www.estcp.com/Program-Areas/Environmental-Restoration/Contaminants-on-Ranges/Identifying-and-Evaluating-Sources/ER-200918/ER-200918

d. Metal Residue Deposition from Military Pyrotechnic Devices and Field Sampling Guidance, May 2012. http://handle.dtic.mil/100.2/ADA562327

e. Explosives Dissolved from Unexploded Ordnance, May 2012. http://handle.dtic.mil/100.2/ADA562287

8.3. Statistical Tools for Site Characterization.

8.3.1. MEC.

8.3.1.1. At present, there are two commonly used statistical software packages for developing geophysical approaches for MEC site characterization: VSP and UXO Estimator.

Each of these statistical tools is based on statistical assumptions that are only applicable to some project sites and for specific purposes. This subsection provides more guidance on the specific application of these tools and how variations of input in the software affect the amount of resulting investigation that is required at a site. Varying input values within these software tools based on site-specific information and the DQOs for the project can create significant differences in the amount of required investigation. The qualified geophysicist, through the TPP process, must determine what the most appropriate software inputs are for the CSM to meet the project DQOs. These statistical tools must be used with care and consistent with the CSM and goals and objectives of the site characterization. Violating the statistical assumptions that underlie the software may result in developing a technical approach that:

a. is inappropriate for a particular site;

b. does not adequately define the nature and extent of contamination at a site;

c. includes too much investigation for the data needs of the project; or

d. includes too little investigation to meet the data needs of the project.

8.3.1.2. Additional statistical tools may be developed in the future, so the geophysicist should review the EM CX Web site for the most up to date available tools.

8.3.1.3. VSP is a software package developed by Pacific Northwest National Laboratory (PNNL) that provides simple, defensible tools for defining an optimal, technically defensible sampling scheme for site characterization and for post-remediation verification (PRV) sampling. VSP contains several tools for statistical site characterization protocols of sites potentially impacted by UXO. These site characterization protocols help identify and delineate potential target areas at a site using specified amounts of geophysical transect data. Tools within VSP that aid the geophysicist in locating and characterizing target areas include approaches for transect design, target area identification, boundary delineation, geophysical anomaly density mapping, and PRV sampling. Although data derived from VSP designed transects can be used to estimate MEC/acre, VSP tools currently are being added to explicitly determine transect survey requirements with the goal of achieving an upper confidence bound on the UXO density estimate that is no higher than some desired upper bound. These tools also provide an upper limit of the number of UXO that may be present throughout an area presumed not to be impacted by concentrated munitions use and support hypothesis testing that there is less than a certain UXO density within an area. VSP is freely available software and may be downloaded from http://vsp.pnnl.gov/. In order to be qualified to use VSP, a member of the PDT is required to attend VSP training.

8.3.1.3.1. Transect surveys can be generated within VSP to traverse and detect potential CMUAs. The inputs used for the transect design must be based on the site-specific CSM and agreed upon by all project stakeholders during the TPP process. The PDT must choose the desired probability that a particular transect design will both traverse and detect an impact area carefully; decreasing this probability will increase the transect spacing and potentially lead to transects being too widely spaced to detect an actual impact area. Although VSP transect designs are based on numerous inputs, the transect spacing output are largely driven by several key inputs, which include:

- target area size and shape;
- transect width;
- background anomaly density;
- anomaly density above background; and
- probability of traversal and detection.

8.3.1.3.1.1. Target area size and shape vary based on factors such as length of site usage, amount of munitions fired during site usage, the distribution of rounds relative to the target point based on the probable error associated with a weapon, the size and type of munitions used, how munitions were fired at the site, and how close the munitions landed to the target area. Because of the variability in each of these factors, no one size of target area is applicable to all sites. The PDT must determine the appropriately sized target area for the investigation. At present, the VSP user must define the size and shape of a target area in VSP. PNNL is working on incorporating default target area sizes in VSP; however, the geophysicist, UXO technician, and other members of the PDT must decide whether these defaults are applicable based on the site-specific CSM.

8.3.1.3.1.2. The size of a target area is dependent on the distance that fragments from munitions that operated as intended were dispersed from the impact location. Typically, most munitions operated as intended and dispersed fragments out to a distance equal to the maximum fragmentation distance (MFD) for the particular munition. The geophysicist should design the target size as a function of the MFD and may choose to factor for the range probable error ($R_{PE}$) and the deflection probable error ($D_{PE}$) for the particular type of munitions. The $R_{PE}$ is the probable error associated with munitions landing either short or long relative to the target point, while the $D_{PE}$ is the amount of error associated with the munition landing wide of the target point. Figure 8-8 shows an example of using the MFD, $R_{PE}$, and $D_{PE}$ in determining the target area size inputs to VSP. At present, the $R_{PE}$, and $D_{PE}$ are not currently available to the general public, and the PDT should contact the EM CX for the appropriate values to use. The geophysicist also may use a simple multiple of the MFD and assume that the target area is a circular target area. A conservative method to estimate the target area size would be to assume the target area is circular with a radius between 0.5 and 0.75 times the MFD and to not factor for $R_{PE}$ and $D_{PE}$.

8.3.1.3.1.3. The average target area anomaly densities requested as input and provided as output in VSP are in terms of density above background. For example, if the background anomaly density were 10 anomalies per acre, then for a target area where the average density is 80 anomalies per acre above background, the actual target area density would be assumed to be 90 anomalies per acre.

8.3.1.3.1.4. Figure 8-9 shows VSP-generated plots of the general variation of probability of traversal and detection of a circular CMUA as a function of the transect spacing for three different radii target areas. Note that smaller radius CMUAs require a smaller transect spacing to ensure the same probability of traversal and detection. Also note that increasing transect spacing decreases the probability of traversal and detection of the target area. The geophysicist should perform a similar site-specific evaluation within VSP of the effect of the target area radius on the probability of traversing and detecting the CMUA.

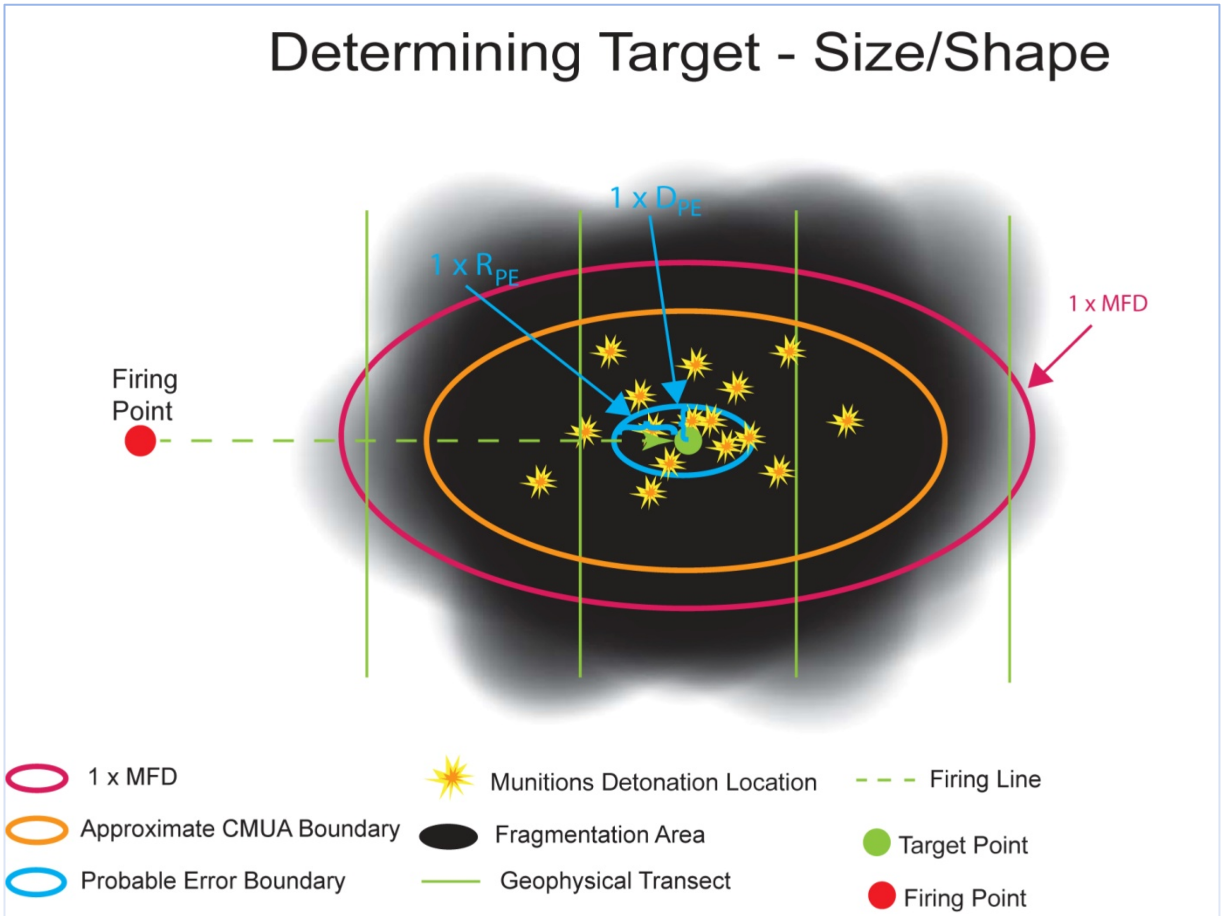



Figure 8-8: Example Determination of Target Area Size and Shape Using the MFD, $R_{PE}$, and $D_{PE}$ (Modified from URS Group, Inc, 2009.)

8.3.1.3.1.5. Transect width typically is driven by the particular geophysical instrument and approach taken to investigate a site. Many times, the actual geophysical instrument footprint (e.g., 1 m wide for the EM61-MK2) may not be the actual detection footprint since the instrument also detects anomalies that may be located outside the instrument footprint. In order to determine the detection footprint of the geophysical sensor, the geophysicist may use the IVS to determine the lateral extent to which the geophysical sensor can detect anomalies or the geophysicist may assume that the sensor detects to a certain distance outside of the instrument footprint (e.g., 0.1 m outside the EM61-MK2 for a total detection footprint of 1.2 m). In addition, stringing multiple instruments together in an array (e.g., two EM61-MK2 arranged adjacent to each other, two UXO technicians sweeping adjacent 3-foot-wide swaths) may be advantageous to collect more data per transect. Some project sites with dense vegetation or difficult terrain may preclude the use of larger instrument arrays.

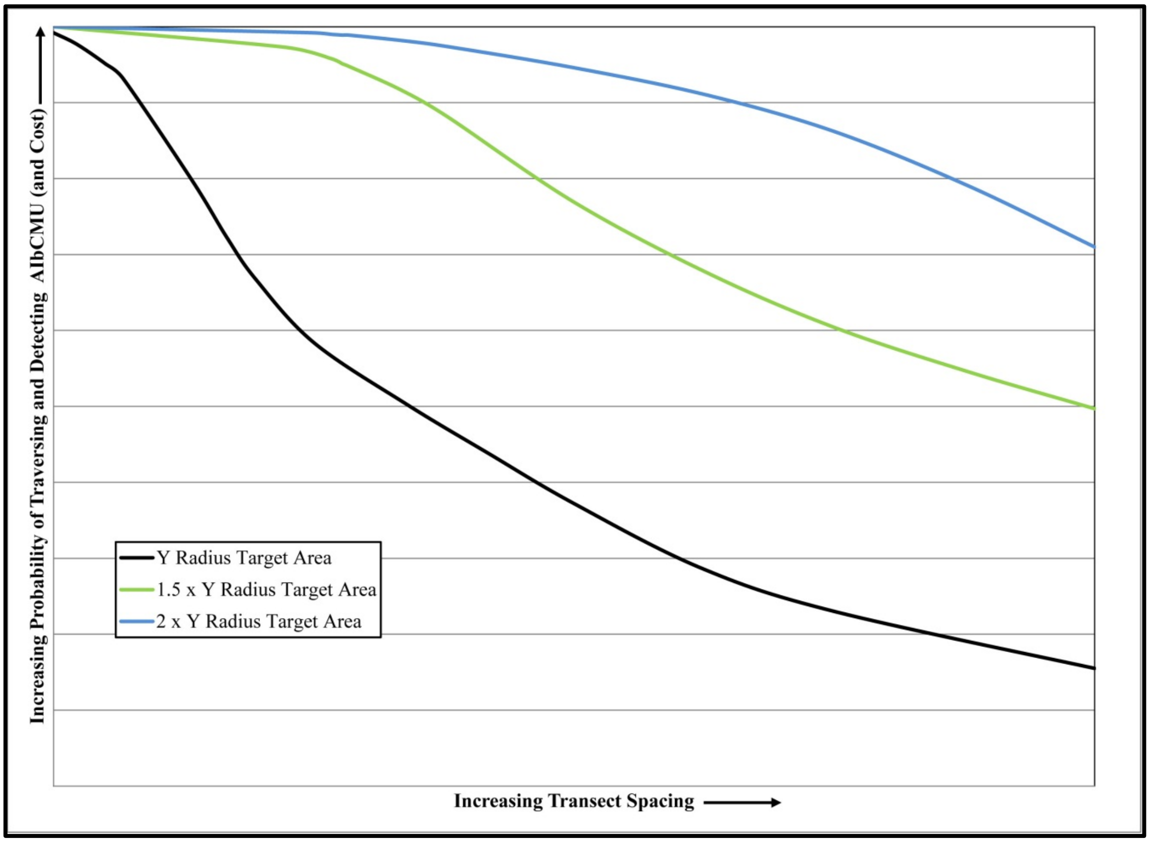



Figure 8-9: Probability of Traversing and Detecting a CMUA as a Function of Transect Spacing for Three Differently Sized Impact Areas

- Figure 8-10 shows VSP-generated plots of the general variation of probability of traversal and detection of a circular target area as a function of transect spacing for three different instrument footprints. Note that widening the instrument footprint improves one's chances of detecting a target area of a given size for any given transect spacing. Thus, to achieve the same probability of traversal and detection with a wider instrument footprint, the spacing between transects increases. Also note that increasing the transect spacing decreases the probability of traversal and detection of the target area.

- It should be noted that this is an example given very specific input and is not likely to be directly applicable to any given site. The geophysicist should perform a similar site-specific evaluation of the effect of the instrument footprint on the probability of traversing and detecting the CMUA.

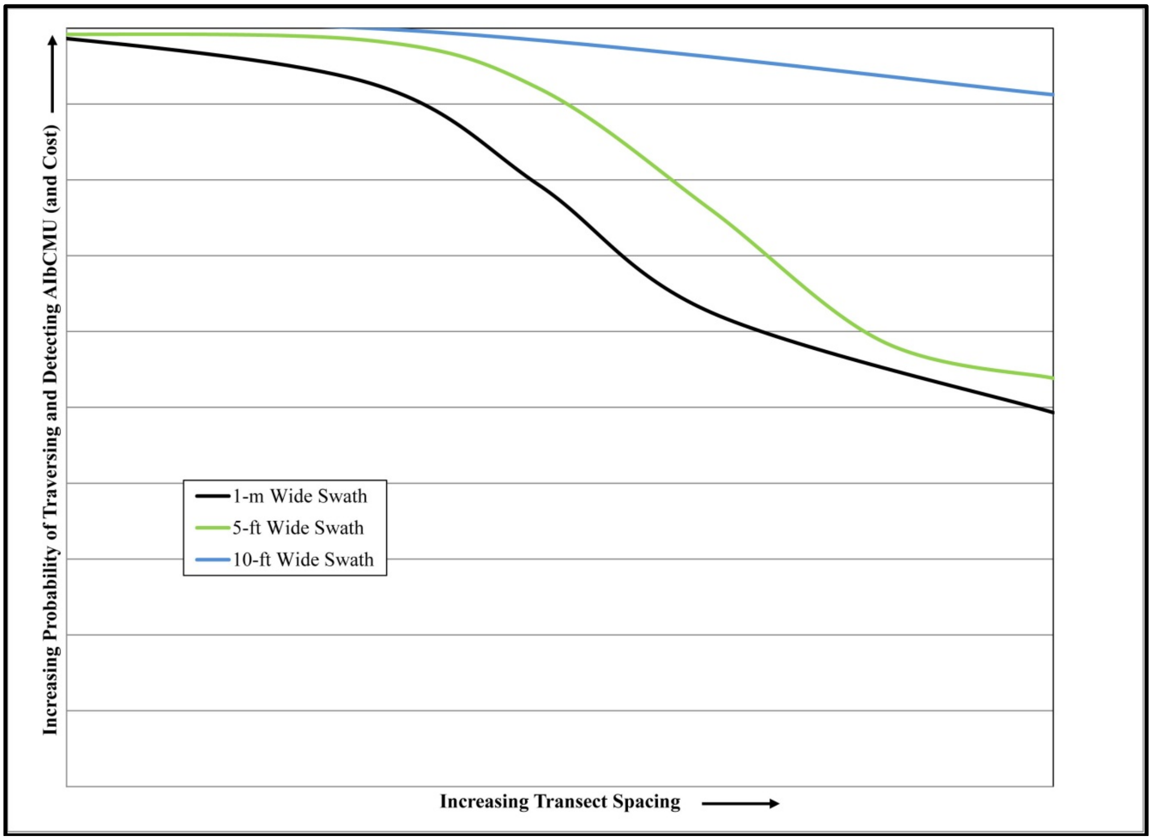



Figure 8-10: Probability of Traversing and Detecting a CMUA as a Function of Transect Spacing for Three Different Transect Widths

8.3.1.3.1.6. The background and target area anomaly densities at a site play a critical role in the transect design developed in VSP. Actual anomaly densities from previous investigations or determined during site visits should be used when these data are available. If accurate background and target area anomaly densities are not known, the geophysicist should choose appropriate anomaly densities given the CSM. It is often prudent to be conservative in the selection of anomaly densities at a site to ensure that the transect design both traverses and detects a target area.

- Figure 8-11 shows VSP-generated plots of the variation of probability of traversal and detection of a circular target area as a function of anomaly density within the target area above background for transects spaced 50 m, 75 m, and 100 m apart. Note that increasing the target area anomaly density above background increases the probability of traversal and detection of the target area. Also note that increasing the transect spacing decreases the probability of traversal and detection of the target area for a specific target area anomaly density above background.

- It should be noted that this is an example given very specific input and is not likely to be directly applicable to any given site. The geophysicist should perform a similar site-specific evaluation of the effect of the average anomaly density above background on the probability of traversing and detecting the CMUA.

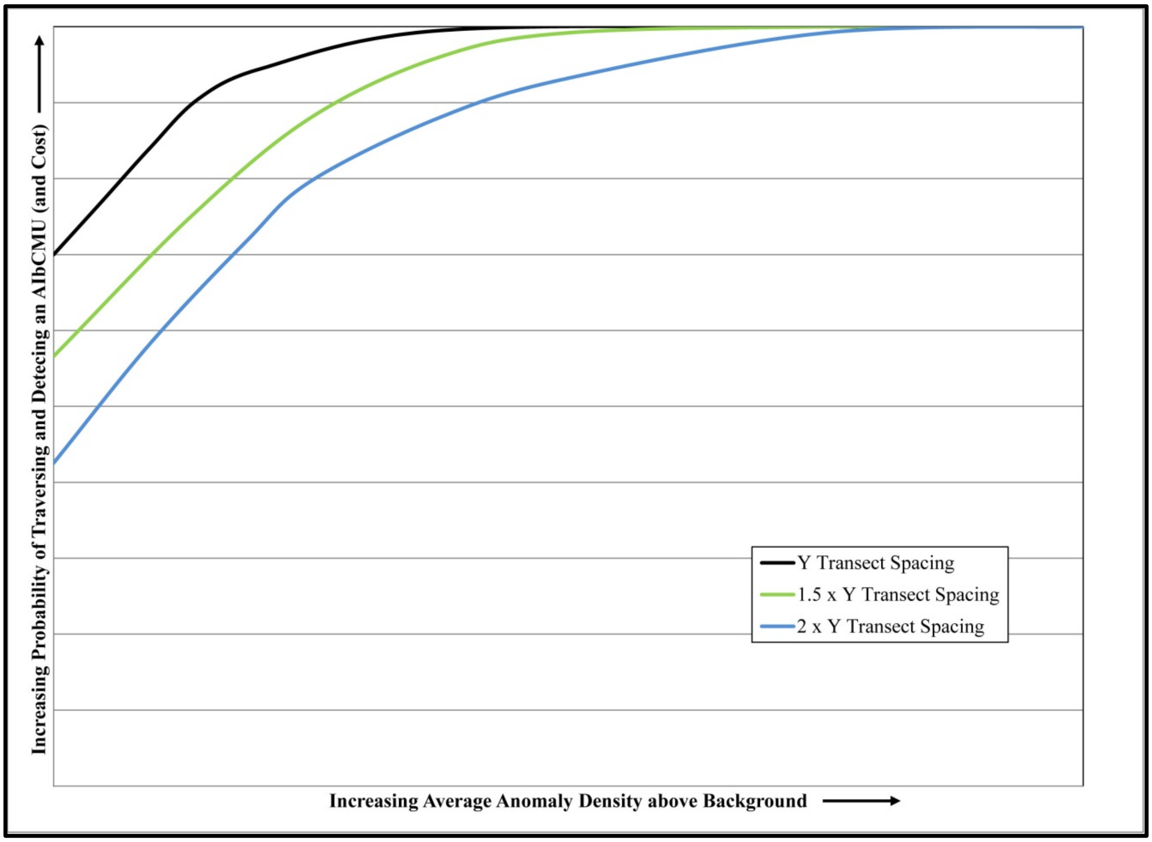



Figure 8-11: Probability of Traversing and Detecting a Circular CMUA as a Function of Average Anomaly Density Above Background for Three Different Transect Spacings

8.3.1.3.2. The target area identification tool within VSP enables the geophysicist to analyze anomalies identified during geophysical transect surveys. The tool flags areas with elevated anomaly density relative to background that may be indicative of target areas. The transect paths investigated and the anomalies identified during the transect survey are used to determine the average anomaly density within a circular window around a segment of the transect and the critical anomaly density selected as an indicator of potential target area anomaly density. The window diameter and critical anomaly density greatly affect the amount of areas that are flagged. The qualified geophysicist, or designee, should evaluate multiple window diameters and critical anomaly densities to see what is most appropriate given the data. Using too large of a window diameter may result in smoothing out of high anomaly density areas, while using too small of a window diameter may result in identifying a significant quantity of small, high anomaly density areas that aren't necessarily associated with the impact area of interest.

8.3.1.3.3. Anomaly density estimation and mapping is commonly performed on geophysical data collected along transects to determine the anomaly density and distribution across a project site, as well as to determine the locations of potential impact areas. Anomaly density mapping also may be critical in developing cost estimates for removal actions to be conducted in later phases after site characterization has been completed. Anomaly density mapping uses known locations of anomalies and traversed transects and uses this information in a geostatistical model to interpolate the anomaly density between data collection points. Figure

8-12 shows an example of a geostatistical map of anomaly density derived from transect data collected at a project site. Maps such as this can be used to delineate areas that may be potential impact areas.

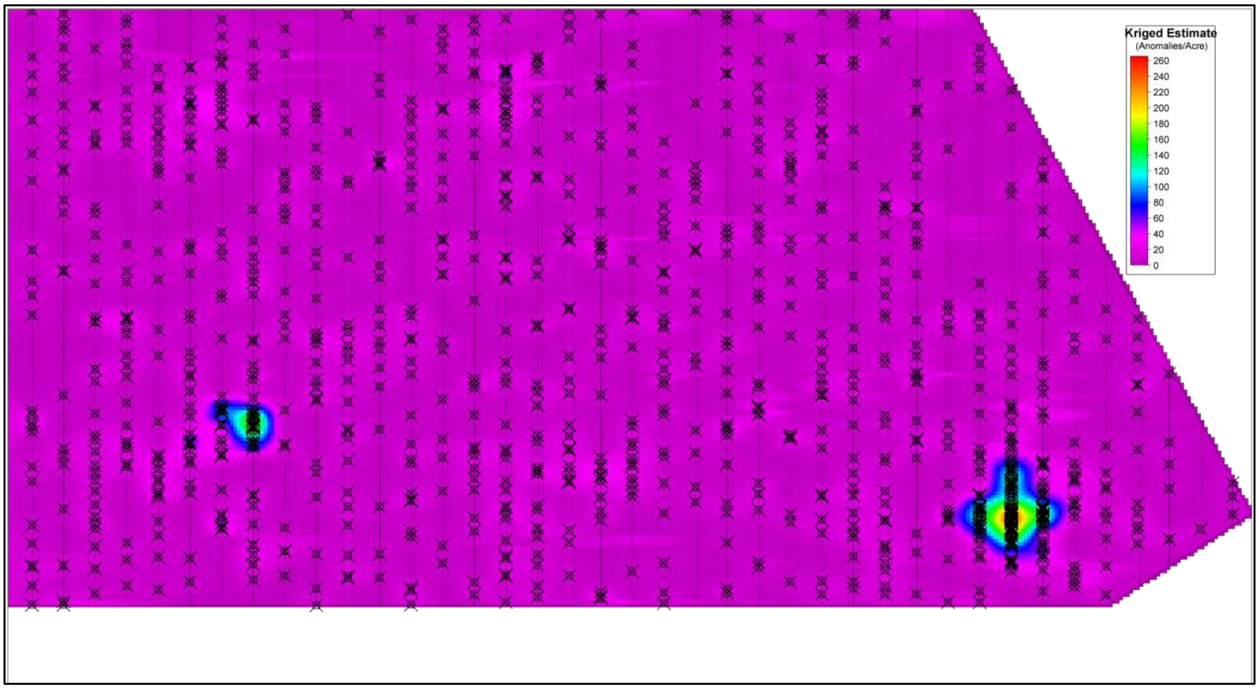



Figure 8-12: Example of a Geostatistical Analysis of the Anomaly Density for an MRS

While the discussion in this section is focused on the use of VSP, the PDT may choose to use other geostatistical tools (e.g., ESRI's ArcGIS software, Golden Software's Surfer) to map anomaly density across a project site. The user must determine what appropriate input values are when using geostatistical tools to map anomaly density. These choices should be based on the design of the investigation. A critical factor in the successful use of the geostatistical tool is determining the appropriate window diameter over which anomalies should be averaged. The VSP user should evaluate multiple window diameters and ranges of anomaly density to determine what is appropriate given the project site. Figure 8-13 shows an example evaluation of anomaly density using 200, 300, 400, and 500 m window diameters.

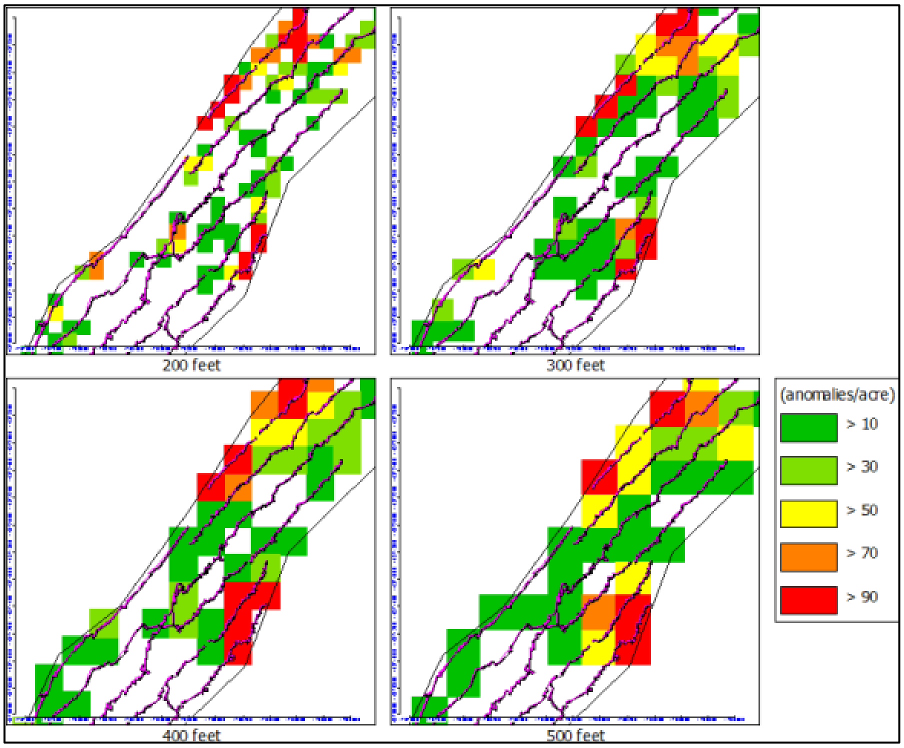



Figure 8-13: Example of an Evaluation of Anomaly Density Mapping Results Given Window Diameters of 200, 300, 400, and 500 ft

The following are key questions the VSP user should evaluate and answer prior to applying VSP's geostatistical tool to map the anomaly density across an MRS:

- What is the most appropriate averaging window size? The averaging window size in VSP defines the size of a centered circular window in which an anomaly density determined. An appropriate window diameter is dependent on the size of the TOI and the spacing between transects. An optimum window diameter has sufficient traversed area within the window and does not include such a large area that potential elevated anomaly density areas are smoothed, or averaged, out by the surrounding background anomaly density areas. A common approach is to use the largest window diameter that only includes one transect and then evaluate how changing the window diameter affects the anomaly density results.

- What is the most appropriate variogram model? A variogram is a measure of the spatial variation of the data. In general, a qualified geophysicist should use the variogram model (e.g., spherical, exponential, Gaussian) and variogram parameters (i.e., nugget, sill, and range) that minimizes the RMS error between the model and actual data.

- What are visual differences when the density map color scale is changed? Changing the color scale can change the shape and size of areas with elevated anomaly density areas.

8.3.1.3.4. The PRV sampling tool in VSP is designed to help develop post-remediation sampling approaches to determine whether the remediation process has been effective, such that few if any TOIs might remain. The tool is designed to help determine whether there is UXO remaining on the site to a specific confidence level. The PRV sampling tool uses a compliance sampling approach to determine how much of the MRS should be geophysically surveyed and anomalies excavated and where the surveys should be placed. There are two sampling approaches that can be used:

- Anomaly compliance sampling
- Transect compliance sampling

8.3.1.3.4.1.1 The PRV tool can aid in developing a sampling approach to determine to a statistical confidence level (e.g., 95%) that some percentage (e.g., 95%) of the anomalies are not UXO. Given that the actual number of UXO is typically very small prior to doing a removal action within a CMUA (typically less than 1%–5% of the total number of anomalies), the PDT is likely to have a high confidence that there are very few UXO on the MRS prior to conducting field activities. Because the odds of finding UXO are so minimal, PRV sampling should be applied to determine if anomalies meeting anomaly selection criteria (e.g., TOI) were missed during the removal action. Missing TOI during the removal action may indicate there was a problem with the process of developing the anomaly selection criteria.

8.3.1.3.4.1.2 Both VSP PRV tools are highly dependent on the detection capability of the geophysical sensor (see Section 6.6.2) and the quality of the geophysical sensor used. It should be noted that only those anomalies with characteristics of UXO need to be excavated. In addition, both tools require that all excavated anomalies are not TOIs to meet the confidence level requirements. Both VSP PRV methods are checks on the anomaly selection process (i.e., they verify that the anomaly selection process employed on an MR project was the right anomaly selection process). The amount of intrusive investigation is based on the goal of the PRV and may require either:

- investigation of all anomalies to determine whether an anomaly was missed; or
- investigation of only TOI anomalies to check whether all required anomalies were removed.

8.3.1.3.4.1.3 Anomaly Compliance Sampling. The anomaly compliance sampling approach requires that all of the anomaly locations are used as input to the PRV sampling tools to determine a select number of anomalies that must be dug or classified and found not to be TOIs to ensure a specific confidence level on the effectiveness of remediation and the number of TOIs that may remain on the site. The anomaly compliance sampling approach is valid when the likelihood of finding UXO is the same throughout the NCMUA (i.e., there is a homogeneous distribution of UXO across the site). Post-anomaly resolution sampling approaches can be designed to answer the following questions:

- How many digs are required to verify the intrusive investigation cleared each hole?
- How are non-digs verified (i.e., test the anomaly classification process on an entire lot)?
- What are the acceptance criteria for a dataset with no digs (e.g., if advanced EMI sensors and anomaly classification are used and no TOIs are identified within a dataset)?
- What are the failure criteria for digs?

8.3.1.3.4.1.4 Transect Compliance Sampling. The transect compliance sampling approach is a useful alternative to the anomaly compliance sampling approach when geophysical surveying costs are relatively high (e.g., the MRS is large). Transect compliance sampling is post-removal action verification that the PDT has met the decision document goals. It can be used to develop a sampling design that includes a limited transect survey of the site and requires 100% of anomalies identified on the transects be dug or classified and found not to be TOIs to ensure a specific confidence level on the effectiveness of remediation and the TOIs that may remain on the site. All detected and excavated anomalies must be non-UXO to meet the original statistical confidence levels on the amount of UXO that may remain at the site. The transect compliance sampling approach is valid when the likelihood of finding UXO is the same throughout the NCMUA (i.e., there is a homogeneous distribution of UXO across the site).

8.3.1.3.5. PNNL is working with ESTCP and USACE to develop new RI modules within VSP that will provide additional design and analysis functionality. The RI tools will augment the WAA options currently in VSP (e.g., transect design and geostatistical analysis tools) and will include transect survey design (updated from the current version), statistical estimate, tests of hypotheses, and spatial analyses for areas suspected to be CMUAs, NCMUAs, and presumptively munitions-free regions. A module is being developed to aid PDTs in developing transect designs and statistical evaluations to support decisions at sites that are presumptively clean. This module will include statistical methods similar to UXO Estimator to estimate the UXO density at an MRS, as well as other Bayesian options that have the potential of reducing the required survey acreage coverage. Review the PNNL Web page (http://vsp.pnnl.gov/) for the most up-to-date release and information on VSP.

8.3.1.4. UXO Estimator is a statistical software package developed by USACE to test the null hypothesis that there is less than a certain UXO density within an area presumed not to be impacted by concentrated munitions use (i.e., an NCMUA) and to estimate the upper bound on the potential residual UXO remaining within an MRS. NCMUAs may consist of an entire MRS (e.g., training and maneuver areas) or portions of an MRS (e.g., buffer areas). The geophysicist must determine the appropriate inputs to use in UXO Estimator through the TPP process to meet the project's DQOs. After site characterization sampling has occurred based on the null hypothesis, UXO Estimator can be used to determine if the null hypothesis is confirmed or whether it should be rejected. In addition, evaluation of site characterization results in UXO Estimator enable the PDT to determine an upper limit on the UXO density and total number of UXO that may remain on an NCMUA after the site characterization is completed. The actual number of UXO that may remain on an NCMUA after site characterization may be any number of UXO between 0 and that upper bound. UXO Estimator is an appropriate statistical tool to use during site characterization to determine the upper bounds on the residual TOIs remaining on an MRS to a specific confidence level. UXO Estimator is freely available software and may be obtained from the USACE EM CX. See the following Web page for details on obtaining UXO Estimator:
http://www.hnd.usace.army.mil/oew/ProcToolsReports/UXO_Estimator_Description.pdf.

8.3.1.4.1. The underlying assumption of UXO Estimator is that there is an equal likelihood of finding a "failure" (i.e., UXO) anywhere in the NCMUA. Another way of stating this assumption is that UXO is distributed randomly throughout the NCMUA and there is a uniform probability or equal likelihood of UXO occurrence over the entire NCMUA. This assumption must not be violated. However, not all CSMs will fit this assumption. Many MRSs are unlikely to have a uniform probability of UXO occurrence across the entire MRS. If an MRS has areas within it that are likely to have different likelihoods of finding UXO, these areas must be treated separately. For example, a mortar range likely will have a higher UXO concentration within the CMUA (e.g., target area) than within the NCMUA (e.g., buffer area outside the target area). When an NCMUA has areas with varying UXO concentrations, the geophysicist should develop specific DQOs and null hypotheses through the TPP process for each of these areas. In addition, each of these areas should be evaluated separately after the PDT has collected site characterization data.

8.3.1.4.2. It should be remembered that mobilization/demobilization and other fixed costs can be relatively high when compared to total geophysical investigation costs at small project properties. Therefore, at small project properties, it is often more cost effective to geophysically investigate the entire location rather than use statistical surveying.

8.3.1.4.3. UXO Estimator consists of three modules:

- Module 1: Develops a field sampling plan for a geophysical investigation (see below)
- Module 2: Analyzes field data after the investigation has been completed (see below)
- Module 3: Unit Conversion

8.3.1.4.4. Module 1 in UXO Estimator is designed to develop field sampling plans for sites to show that there is less than a certain UXO density on a site, given a desired confidence level. Given the three inputs to UXO Estimator (i.e., site size, UXO density per acre, and confidence level), the output is a minimum number of acres of geophysical investigation that needs to be conducted to confirm that the site has less than the specified UXO density at the specified confidence level if no UXO are found in the investigation. The geophysical investigation area may be implemented as randomly placed grids or transects within the project site. The output of UXO Estimator module 1 is the amount of acreage that must be covered; however, the software does not provide a basis for the size or location of the grids or transects. The geophysicist must determine the size and spatial distribution of the grids and/or transects to meet the site-specific DQOs. Only those anomalies with characteristics of UXO need to be excavated.

8.3.1.4.4.1. UXO Estimator is similar to the VSP PRV sampling tool in that they both test hypotheses about the residual UXO left on a site; however they differ in that UXO Estimator test to an x% confidence that the UXO density is less than a certain amount, while VSP test to an x% confidence that a percentage of the anomalies/transects are not UXO.

Variations in the UXO Estimator input can lead to significant variations in the output. Figure 8-14 shows UXO Estimator generated plots of the variation of required area of investigation as a function of confidence level for three example UXO densities for a constant site size. Figure 8-15 shows UXO Estimator generated plots of the variation of required area of investigation as a function of site size for three example UXO densities with a constant confidence level. Figure 8-16 shows UXO Estimator generated plots of the variation of the required area of investigation as a function of UXO density for three specific confidence levels. Based on Figures 8-14 through 8-16, it is apparent that the required amount of investigation increases when:

- a higher confidence level is selected;
- a lower UXO density is selected; or
- the site size increases.

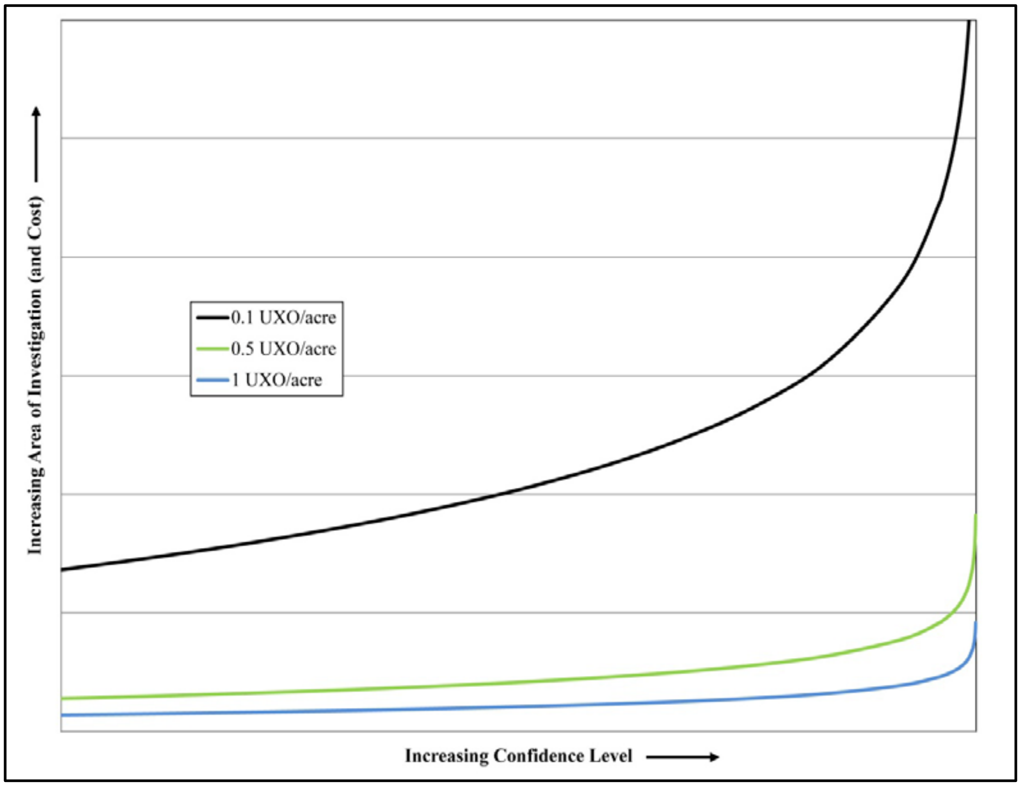



Figure 8-14: Variation of Required Area of Investigation as a Function of Confidence Level for Three Example UXO Densities with a Constant Site Size. Plots were generated in UXO Estimator.

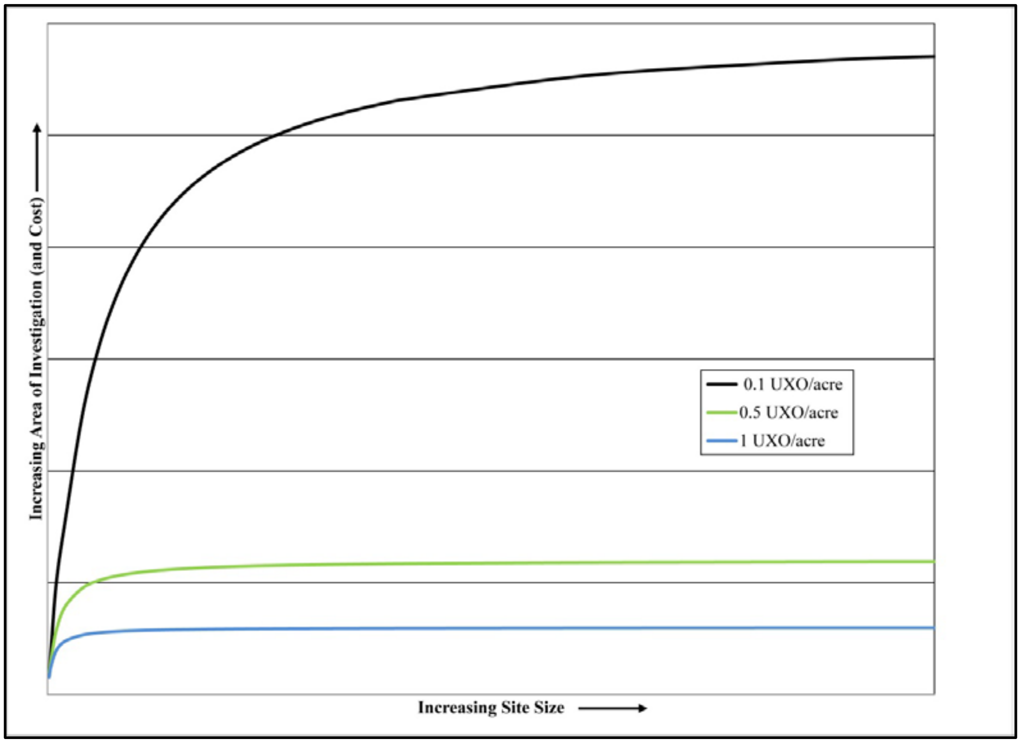



Figure 8-15: Variation of Required Area of Investigation as a Function of Site Size for Three Example UXO Densities with a Constant Confidence Level

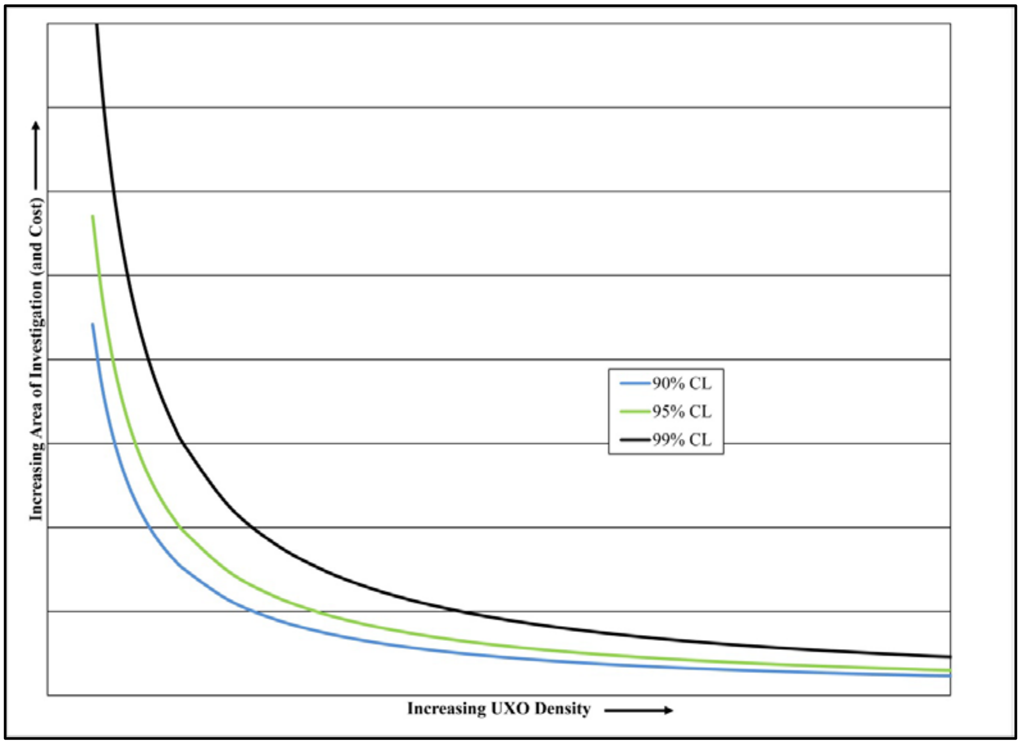



Figure 8-16: Variation of the Required Area of Investigation as a Function of UXO Density for Three Specific Confidence Levels with a Constant Site Size

8.3.1.4.4.2. Increased confidence levels and lower UXO densities have a much greater affect than site size on the amount of investigation output by UXO Estimator. The PDT must make decisions on appropriate input values for the CSM and project DQOs. The UXO Estimator help menu provides general guidance on UXO density inputs; however, the PDT must choose the appropriate UXO density for the project DQOs to satisfy concerns of project stakeholders about the upper bound of the number of MEC potentially remaining at a site after an investigation and for other factors. Testing for lower UXO densities does not alter the actual number of UXO that may be present on a site after characterization activities are complete or remedial activities are complete. Nor does testing for lower densities suggest the actual number is closer to zero. Having a higher confidence in the upper bound (e.g., testing for a 95% confidence as opposed to an 85% confidence) or testing for a lower concentration (e.g., testing for an upper bound of one UXO per 10 acres as opposed to one UXO in 4 acres) is not expected to change the general response actions required for the MRS. Typical UXO density input for UXO Estimator will range between 0.1 and 1.0 UXO/acre for NCMUAs. Often, the key drivers for selection of the UXO density are the selection of the criteria for deciding whether the site is impacted by concentrated munitions use, stakeholder concerns, and costs. Lower UXO densities require greater investigation (and cost), and the PDT must decide whether the additional investigation would provide significant information to guide future project decisions and selection of the remedial action alternative.

8.3.1.4.4.3. For a given UXO density, the theoretical number of UXO on the MRS increases with increasing MRS size. Thus, the odds of encountering a UXO during sampling quickly increases with the increased number of UXO on the site. Because of this, the amount of investigation required by UXO Estimator, as shown in Figure 8-15, reaches a point at which the amount of required investigation only increases slightly as the site size increases for larger sites.

8.3.1.4.4.4. In considering the above UXO densities, the PDT should evaluate the potential residual hazards that are acceptable to stakeholders given the current and reasonably anticipated future land use. If the PDT performs an investigation of a 1,000-acre MRS and finds no UXO, the PDT would be confident (to whatever statistical confidence level was used and for the amount of investigation performed) that there were the following amounts of UXO remaining on the site:

- If the investigation was developed using 0.1 UXO/acre: Between 0 and 100 UXO remain on the MRS after the investigation is completed.

- If the investigation was developed using 1.0 UXO/acre: Between 0 and 1,000 UXO remain on the MRS after the investigation is completed.

8.3.1.4.4.5. Although the results indicate that there is a broad range of potential residual UXO remaining within the MRS, this set of data is likely only one piece of the entire dataset for an MRS. For example, additional site information may allow the PDT to qualitatively determine that the residual UXO on the MRS may be closer to zero. Additional data that the PDT may use in assessing the potential residual UXO include previous investigation results (e.g., SI, EE/CA investigation data), historical range information (e.g., range layout drawings, interviews with former site personnel), and historical aerial photography, which may show the MRS was never heavily impacted (e.g., limited cratering during the years of use). When evaluating the dig results of previous investigations, the PDT should consider the source of anomalies that were dug (e.g., analog geophysical vs. DGM) and whether any of them were munitions-related. Identification of MD in this data indicates that the area may have UXO, while a lack of MD may add further weight that the number of residual UXO is closer to zero.

8.3.1.4.4.6. Note that a key assumption in UXO Estimator is that the entire output acreage will be investigated (i.e., all anomalies with characteristics of UXO identified within areas of investigation should be excavated). The PDT may choose to investigate the resulting area with either grids or transects, so long as they are placed randomly within the NCMUA. VSP has tools that can be used to generate the random locations of grid center points (e.g., the "non-statistical sampling approach → predefined number of sample" tool) and transects (use the post-dig verification sampling).

8.3.1.4.5. Module 2 in UXO Estimator is designed to analyze field data to determine whether site characterization results support the null hypothesis (i.e., there is less than a certain UXO density to a specific confidence level) or whether the null hypothesis should be rejected (i.e., one or more UXO were found during the investigation, which indicates the UXO density may be higher than originally assumed at the specified confidence level). If the PDT wishes to test for the null hypothesis and only investigates the amount of area calculated in UXO Estimator, that null hypothesis can only be confirmed if UXO are not found during the investigation. Identification of one or more UXO without additional sampling results in rejection of the null hypothesis unless additional or previous sampling results are included in the analysis.

8.3.1.4.5.1. If one or more UXO is found during the initial survey, the PDT has the option to augment the investigation by surveying additional acreage or, using Module 2 in UXO Estimator, to calculate the upper confidence bound on the UXO density estimate and evaluate through the TPP process whether that result is acceptable. If additional acreage is surveyed, Module 2 in UXO Estimator can be used to determine how many more acres must be investigated, with no UXO found, to meet the DQOs provided. It should be noted that there is no guarantee that additional surveys would meet the original TPP DQOs since additional UXO could be encountered. If UXO is found during the investigation, the PDT decides to conduct additional investigation to test the original null hypothesis, and UXO are not found during subsequent investigation, then the null hypothesis can be confirmed. Module 2 inputs include the same input from Module 1 plus the number of acres investigated and the number of UXO found during the investigation. Using these inputs, the module calculates the confidence level that the entire site has less than the UXO density DQO that was established through the TPP process (e.g., 0.5 UXO/acre).

8.3.1.4.5.2. Table 8-1 presents an example DQO hypothesis and test to determine the upper limit of UXO present within an NCMUA. If UXO is found during the investigation and the Module 2 calculations indicate that the desired statistical confidence level hasn't been met, the PDT has at least three options:

Table 8-1: Site Characterization Hypothesis Testing

| Area | Hypothesis | Hypothesis Test | Results Evaluation |
|---|---|---|---|
| NCMUA | No munitions were targeted within the area outside a CMUA and there is less than y UXO per acre across the site. | The PDT uses UXO Estimator to develop a sampling plan that consists of z acres of grids or transects to prove to a x% confidence level that there is less than y UXO/acre. | The PDT performs geophysical surveys and excavation of anomalies within the z acres. If no UXO are found within the grids, then the PDT can be x% confident there is less than y UXO/acre. If UXO are found, the PDT can perform additional sampling and find no more UXO to be x% confident there is less than y UXO/acre or calculate a revised, larger upper bound on the number of UXO/acre and determine if that larger UXO density is acceptable. |

8.3.1.4.5.2.1 Option 1. The PDT may determine that it is essential that the desired statistical confidence levels used to develop the field sampling plan must be met. In this option, the PDT can use the Module 2 output to determine the amount of additional investigation to conduct. If no additional UXO are found within the additional areas of investigation, then the PDT has determined that the UXO density is less than the initial desired confidence level. If additional UXO is found during the subsequent phases of investigation, the PDT eventually must reject the original assumptions of the UXO density at the site and accept that some higher density of UXO is present.

8.3.1.4.5.2.2 Option 2. The PDT may determine that, although the original null hypothesis test was rejected due to finding UXO during the site characterization activities, a modified null hypothesis test based on the results of the investigation is sufficient to meet the project's site characterization objectives. In this scenario, the PDT evaluates the site characterization results and calculates a decreased confidence level and/or an increased UXO density based on those results.

8.3.1.4.5.2.3 Option 3. The PDT may determine that, although the desired confidence level wasn't met, they may use a weight-of-evidence approach to evaluate if the project's DQOs were met without recalculating new confidence levels or UXO density. The PDT may use the site characterization results plus previous investigation results or other lines of evidence (e.g., aerial photographs, no MD finds, public usage of MRS without UXO finds) indicate that the actual confidence level and the weight of all evidence for all available data is sufficient to meet the needs of the project DQOs and no additional data need to be collected.

8.3.1.4.6. Module 3 in UXO Estimator allows the user to perform linear unit conversions, perform area unit conversions, and calculate the number of grids required to meet the acreage requirements developed in Module 1. The linear unit conversion allows the user to input a distance in feet, meters, or miles, and then the software calculates the distance in the other two units. The area unit conversion allows the user to input an area in units of acres, square feet, or square meters, and the software calculates the area in the other two units. The grid calculation allows the user to input the total acres of investigation, the size of the grids in feet or meters, or the total number of grids to be investigated, and then the software calculates the remaining values.

8.3.1.4.7. The following is an example. A PDT wants to determine the likelihood that a 2,000-acre training and maneuver area has less than 0.1 UXO/acre (or less than 200 MEC across the entire site) to a 95% confidence level. Using UXO Estimator, the PDT calculates that they need to perform a minimum of 29.59 acres of investigation but increase the amount of investigation to 30.07 acres (or 131 100-foot x 100-foot grids). The geophysicist randomly places the grids throughout the NCMUA, performs geophysical surveys, and the dig team excavates all anomalies that could be TOIs within the grids. The dig team identifies one UXO within the NCMUA. Using UXO Estimator Module 2, the project geophysicist evaluates their data and determines the following:

- They can be 80.64% confident there is less than or equal to 0.1 UXO/acre in the NCMUA. Therefore, sampling was inadequate to meet the target density at the 95% confidence level. 16.695 more acres must be sampled with no additional UXO found to meet the specified target density of 0.1 UXO/acre with 95% confidence. Although the PDT has not met the original assumptions, they have proven to a 95% confidence level that there is less than 0.157 UXO/acre (or 314 UXO) across the site.

- The PDT has determined that the lower confidence level for the initial DQO of 0.1 UXO/acre (or a slightly higher UXO density at the 95% confidence level) is acceptable because UXO wasn't found in previous investigations, historical information indicates the site was used for a relatively short period of time, and there is no history of public exposure at the MRS. Although the PDT has not met the original assumptions, they have proven to a 95% confidence level that there is less than 0.157 UXO/acre (or 314 UXO) across the site; therefore, the PDT decides that no additional investigation is required to meet the project's DQOs.

8.3.2. MC.

8.3.2.1. There are two main categories of sampling designs: probability-based designs and biased (non-probabilistic or judgmental) designs. Probability-based sampling designs apply sampling theory and involve unbiased selection of materials from throughout a sampling unit such that every particle within the sampling unit has an equal probability of being incorporated into the sample. Probability-based sampling allows for estimation of sampling error using statistical methods. Biased sampling designs involve the selection of samples on the basis of site understanding and professional judgment (e.g., targeted sampling at known impact areas). Sampling schemes that combine biased and probability-based sampling (e.g., ranked set sampling schemes) are often suited to MR projects. See Guidance on Choosing a Sampling Design for Environmental Data Collection Details for Use in Developing a Quality Assurance Project Plan (QAPP), USEPA QA/G-5S (2002) for details regarding probability-based and biased sampling designs.

8.3.2.2. The statistical software package VSP discussed above initially was developed to support probability-based statistical sampling designs for discrete environmental sampling. The VSP Version 6.0 User's Guide states that it is "a software tool for selecting the right number and location of environmental samples so that the results of statistical tests performed on the data collected via the sampling plan have the required confidence for decision making." USEPA Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA QA/G-4, USEPA, 2006a) (EPA/240/B-06/001)It was designed around the "USEPA Guidance on

Systematic Planning Using the Data Quality Objectives Process" (EPA/600/R-96/055) published by the USEPA in 2000 (updated in 2006). For projects with probability-based discrete sampling designs, VSP has been endorsed by a number of programs. Since its initial release, it has been updated to include options for UXO (as described above) and incremental sampling. IS recently was added as a statistical sampling option to estimate mean analyte concentrations in soils in predefined areas. Although the algorithms VSP uses are mathematically correct, there is concern regarding their unqualified application to develop sampling designs for environmental data. Caution must be used if VSP is to successfully support project objectives for IS sampling for MC. Users need to be aware of the underlying assumptions being made and ensure that they are reasonable for the intended applications. For example, the methods VSP uses to calculate the number of incremental samples required to satisfy tolerances for decision errors assume normality. However, a small number of increments (e.g., < 30) for each incremental sample may not adequately control distributional heterogeneity, resulting in non-normal distributions for the measured contaminant concentrations and inaccurate estimates of the sample sizes (i.e., numbers of data points) needed to satisfy tolerances for decision errors.

8.4. Locating Concentrated Munitions Use Areas.

8.4.1. CMUAs are MRSs or areas within MRSs where there is a high likelihood of finding UXO or DMM and that have a high amount of MD within them as a result of historical munitions use and fragmentation. CMUAs are most commonly target areas on ranges; however, they also include explosion sites, OB/OD areas, and potentially even disposal sites where munitions have been disposed of over a relatively large area (i.e., not small, isolated burial pits). The initial boundary of a CMUA is the line that differentiates between the elevated anomaly density area and the background anomaly density area. The CMUA boundary may be modified and further delineated throughout the intrusive investigations within the CMUA. Numerous sources of information may be used to aid in determining the general location of CMUAs. These include historical and current aerial photography, previous investigations (e.g., HRR, SI), and LIDAR data. These tools may be used to assist with locating range features (e.g., craters, target rings) associated with the CMUA; however, they are unable to fully delineate the boundaries of CMUAs since they are incapable of detecting the individual pieces of MD and UXO.

8.4.2. A geophysical transect survey designed in VSP is the primary method to locate CMUAs. Section 8.3 provides further guidance on the use of VSP to locate CMUAs.

8.5. Characterizing Concentrated Munitions Use Areas.

8.5.1. MEC. Once transects within a potential CMUA have been surveyed using geophysical sensors, the PDT must select an approach to characterize the elevated anomaly density area and, if it is a CMUA, the nature of UXO within the CMUA. The anomaly reacquisition and resolution methods should support the DQOs established by the PDT. If geophysical data along the transects were collected using a positioning method that had sufficient accuracy to reacquire anomalies (e.g., RTK DGPS), then the PDT may choose to dig all anomalies on the geophysical transects. Digging all geophysical transect anomalies may not be practical if the anomaly count is very large. When anomaly counts are very large, the PDT can choose to excavate a selected number of anomalies to determine the nature and extent of UXO within the CMUA. The PDT should focus the sampling approach on collecting the data needed to meet the DQO decisions that are required for the project. It should be noted that the site characterization data needs may not be the same as the remedial design cost estimating data needs. When designing the MEC sampling approach, the PDT should answer the following questions:

a. How critical is it to find all UXO types?

b. Will identifying all MD types be sufficient?

c. Is there a need to estimate UXO distributions?

d. What variables need quantifying in the cleanup cost estimates?

8.5.1.1. Typical decisions for characterizing CMUAs include, but are not limited to, the following:

a. Estimate the number of anomalies within a CMUA.

b. Determine whether the potential elevated anomaly density area is a CMUA or a cultural feature.

c. Determine all of the types of UXO present within a CMUA.

d. Estimate the number of UXO within a CMUA.

8.5.1.2. For many MRSs, and particularly for FUDS MRSs that have been developed since their last DoD use, it is possible that elevated anomaly density areas are present within the MRS that are not associated with concentrated munitions use. The PDT may be able to determine that these areas are not CMUAs based on site reconnaissance data collected during the transect investigation; however, the PDT should perform some amount of excavation to determine that the elevated anomaly density area is not a CMUA. If the PDT performs geophysical and intrusive sampling and finds no evidence of HE-fragments or practice bomb fragments, then the PDT can be confident that the elevated anomaly density area is not a CMUA. If, however, HE fragments, UXO, or practice munitions are found within the production area, then the PDT can conclude that the elevated anomaly density area is a CMUA and proceed to performing additional sampling, as needed, to characterize the CMUA.

8.5.1.3. There are several methods available to characterize CMUAs, including those listed below. Regardless of the site characterization approach the PDT selects, the PDT must engage a qualified statistician to develop a site-specific approach to characterize the CMUA. Whatever approach is selected, the PDT should focus on looking for trends in the dig results. This includes statistical sampling of large populations of anomalies with the goal of digging until enough anomalies have been investigated to detect trends in the dig results.

8.5.1.3.1. Trend Analysis Approach. Trend analysis is the process of collecting data and analyzing that data to identify patterns or trends in the data. As applied to characterizing a CMUA, trend analysis requires sampling until a trend is seen in the dig results. Trends should be defined on a site-specific basis; however, in general, a dig result trend indicates that further intrusive investigation is unlikely to identify new types of TOIs or indications of TOIs (e.g., MD associated with a particular TOI). The PDT should develop a decision point to determine when enough anomalies have been investigated once trends are seen within dig results. The PDT should engage a qualified statistician to evaluate the dig results to determine when a statistically significant sample size has been obtained to characterize the entire population of samples (i.e., the estimated total number of anomalies within the CMUA). In this approach, the dig team may start digging a certain number of grids within the CMUA; however, the dig team would not need to dig all anomalies if a trend is seen in the dig results. If no trends are seen in the dig results (e.g., after digging 20 grids, the dig team is still finding new TOI types), then the PDT should evaluate whether further investigation is required to meet the objectives of the investigation.

8.5.1.3.2. Population Sampling. Population sampling can be used to determine whether an elevated anomaly density area is a CMUA and to characterize an identified CMUA. The below sections describe each approach further.

8.5.1.3.2.1. In order to determine whether an elevated anomaly density area is a CMUA, the PDT should investigate a statistical sample of the anomalies identified along the VSP transects to determine to a project-specific level of confidence that there are no munitions within the elevated anomaly density area. In an elevated anomaly density area where the number of anomalies in the area has been estimated (e.g., using VSP transects), the entire area can be viewed as a population of pieces of metal. Once the total population is determined (i.e., total number of anomalies within the elevated anomaly density area is estimated), the PDT then can use population sampling to determine whether the elevated anomaly density area is a CMUA. The VSP anomaly compliance sampling tool is one tool that can be used to determine the number of anomalies that require investigation to meet a specific statistical confidence level. Using the VSP anomaly compliance sampling tool can only be used to confirm or refute that an elevated anomaly density area is a CMUA; it can't be used to determine the proportion of UXO within an anomaly population within the CMUA.

8.5.1.3.2.2. Population sampling can be used to characterize a CMUA by of digging 100% of targets within grids within the CMUA and summarizing the findings to define the horizontal and vertical distributions. In a CMUA where the number of anomalies in the area has been estimated (e.g., using VSP transects), the entire CMUA can be viewed as a population of pieces of metal. Once the total population is determined (i.e., total number of anomalies within the CMUA is estimated), the PDT can use population sampling to determine the proportion of different types of metal within that population (e.g., the percentage that are 60 mm mortars and MD). The amount of investigation may include a biased number of grids (e.g., 1 acre of 50-foot x 50-foot grids), grids randomly located throughout the CMUA, or a combination of random and biased grids. If the goal of the investigation is strictly to determine the quantity of UXO within the CMUA, then the PDT may decide to only dig potential TOIs. If, however, an objective of the investigation is to identify all the different types of UXO within the CMUA, the investigation may want to include evaluation of the TOIs and non-TOIs (i.e., MD), since it is likely that the quantity of actual UXO within the CMUA is small relative to the total population and the investigation of the non-TOIs may aid in determining the different types of munitions historically used within the CMUA.

8.5.1.3.3. Anomaly Classification Sampling. In anomaly classification sampling, the geophysicist selects a statistical sample of anomalies based on the geophysical characteristics of the anomaly. As discussed in Chapter 6, anomaly classification can mean using several DGM anomaly parameters to determine which anomalies are TOIs or it can mean collecting advanced EMI data and performing an inversion and classification. Either of these approaches may be applied to anomaly classification sampling. The goal of anomaly classification sampling is to identify feature clusters (or a group of anomalies with a similar range of feature parameters) that are indicative of a particular type of metal and digging within that feature cluster to determine the nature of the anomalies. The geophysicist also should look for potential individual anomalies that are not a feature cluster but could be potential TOIs. If the goal of the investigation is strictly to quantify the number of UXO, then it is possible to only dig potential TOIs. Using the anomaly classification approach and only digging TOIs within the relatively small sample size may not identify all types of UXO within the CMUA. If the goal of the investigation is to determine all the types of UXO within the CMUA, then the classification sampling approach should include digging a statistical sample of anomalies within non-TOI feature clusters. For example, if historical site information indicates that 105 mm projectiles were used at an MRS, but the classification results from advanced EMI data do not identify 105 mm projectiles, the project geophysicist could select a statistical sample of anomalies within non-TOI feature clusters to attempt to identify anomalies that may be due to fragments of 105 mm projectiles. If fragments of 105 mm projectiles are then found during intrusive investigation, the PDT has then confirmed the CSM.

8.5.2. MC. MC originate from military munitions; therefore, MC characterization typically is focused in CMUA, as determined by historical document research, WAA, aerial photographs, or the results of a MEC investigation. Sampling and analysis requirements vary based upon site-specific conditions and must be addressed during TPP activities. The subsections below discuss general objectives for soil, surface water/sediment, and groundwater sampling within CMUAs. Figure 8-2 depicts an example decision logic for characterization of MC at CMUAs, and Section 8.8 provides a more detailed discussion regarding sampling of these environmental media.

8.5.2.1. Soil.

8.5.2.1.1. The purpose of collecting soil samples during an MC investigation is to provide a basis for inferring characteristics of the unsampled material within identified and explicitly delineated areas of a project site (i.e., a sampling unit or decision unit). Large portions of a project site may not need to be sampled, based on the CSM and other considerations. The area to be represented by samples must be specifically defined if the sample data are to be considered representative. The degree of this representativeness should be specified in the project's DQOs developed during the TPP process and verified through QC replicate field sampling. An appropriate sampling design should include the physical CSM, size of sampling units, number of increments (if appropriate), and the number of samples.

8.5.2.1.2. Soil analyses should be based on potential MC, if known (see Chapter 7). Close coordination with the MEC investigation team is required to assess locations for MC sample collection. Soil samples should be collected during MEC intrusive investigation at locations where MEC or MD items are found (see Section 8.2.6.5). Besides analyzing for MC, additional soil parameters may be analyzed to assist in MC fate and transport evaluations for risk assessment and/or for evaluation of the feasibility of remedial alternatives for soil or groundwater treatment (see Chapter 10).

8.5.2.1.3. Soil samples should be collected from each area suspected to contain MC, such as known target impact areas, firing points, OB/OD areas, and hand grenade courts, as well as at known MEC/MD locations.

8.5.2.1.4. Sample representativeness should be maximized to the extent practical. IS and sample processing IAW SW8330B, Appendix A, is a protocol that is designed to maximize sample representativeness for soil samples to be analyzed for secondary explosives. IS has the benefits of reducing the number of samples that require analysis, improving data reliability, allowing QC replicates to quantify the precision of estimates of mean concentrations with modest additional effort, and tending to decrease the number of nondetect results and the chances that certain contaminants might be missed at a site. Careful planning is required to implement IS, including establishment of decision units and/or sampling units, determination of sampling depths, and selecting an appropriate number of replicate samples. IS currently may not be accepted by certain state and local regulatory entities. If sampling is to be conducted in a high density MEC environment, MC sampling density must be evaluated relative to safety issues for sampling personnel.

8.5.2.2. Surface Water and Sediment.

8.5.2.2.1. When MC contamination of surface water and sediment is possible through direct deposition of munitions, from runoff, or based on other site conditions, the PDT should provide for sediment and surface water sampling. During project planning, the PDT should consider surface water features, such as flowing surface water bodies (e.g., rivers, streams, seeps, drainage ditches, storm water channels) and standing surface water bodies (e.g., lakes, wetlands, lagoons, surface impoundments). Each of these types of water bodies has underlying sediments that may be a "sink" for MC, slowly releasing substances to the overlying water through dissolution and adsorbed onto suspended particles (colloids). Intermittent drainages also may be considered if they are located in areas prone to flash flooding, which can mobilize sediment during high-energy precipitation events.

8.5.2.2.2. The degree that sediment serves as a sink for MC depends on the physical and chemical characteristics of the MC and the sediment composition. For example, metals and inorganic MC compounds tend to adsorb onto smaller particles, especially clay. Organic MC compounds preferentially adsorb onto organic matter.

8.5.2.2.3. As with soil sampling, the goal of sampling surface water and sediments for MC is to obtain a sample that is representative of the media being evaluated based on the intended use of the data.

8.5.2.2.4. Groundwater.

8.5.2.2.5. The PDT should consider the possibility of groundwater contamination from MC and the need for sampling during project planning based on regulatory requirements; the types, amounts, and likely distribution of any MC that are released; the project site geology/hydrogeology (e.g., depth to groundwater, karst); climate weathering of MC sources; the susceptibility of groundwater to MC contamination from surface releases; and potential receptors.

8.5.2.2.6. Groundwater monitoring wells can provide essential information that is critical for determining depth to the water table from overlying MC sources; groundwater flow directions and gradients; the type of aquifer materials, which influences the characteristics of MC migration; and groundwater quality and the types and concentrations of MC in the groundwater. Refer to EM 200-1-17 for guidance on monitoring well installation.

8.6. Characterizing Non-Concentrated Munitions Use Areas.

8.6.1. MEC.

8.6.1.1. NCMUAs (e.g., non-target areas) may be either entire MRSs (e.g., training and maneuver areas) or areas outside of CMUAs (e.g., buffer areas). Whereas target areas generally will have an elevated geophysical anomaly and UXO density, areas outside target areas likely will have much lower anomaly and UXO density. The underlying assumption of MEC site characterization activities within NCMUAs is that there is an equal likelihood of finding MEC anywhere within the area.

8.6.1.2. Tools to Characterize NCMUAs. The tools available for use in determining the amount of UXO within an area include statistical tools (such as UXO Estimator and VSP's PRV sampling) and random geophysical grid and intrusive investigations. VSP's PRV sampling modules and UXO Estimator are based on similar underlying statistical models; for small sample calculations, the results between the two software programs can vary slightly, although the difference has little practical effect. They both assume that anomalies within the surveyed area will be dug or classified as TOI or non-TOI (or alternatively, UXO or non-UXO). Section 8.3.1 discusses the VSP PRV sampling module and UXO Estimator.

8.6.1.3. Uncertainty in NCMUA Site Characterization.

8.6.1.3.1. Given the large size and limitations of current technologies, it is impossible to say to 100% certainty that all UXO have been identified within an MRS. For NCMUAs, there is no way to determine whether there is zero UXO or DMM on the site. The PDT should build a body of evidence in the CSM to evaluate the uncertainty in the site characterization (i.e., whether UXO or DMM are present at the site after site characterization is completed) by assessing all available information, which should include:

- previous investigation findings (e.g., HRR, ASR, SI);
- historical photographic analysis;
- VSP results;
- UXO Estimator results;
- dig results;

- visual observations during field activities; and
- other sources (e.g., current orthophotos, LIDAR).

8.6.1.3.2. Using a single source of information may lead to incorrect conclusions. For example, if a PDT designed a site characterization approach to determine if there are less than 0.5 UXO per acre on a 1,000-acre site and they found no UXO during the investigation, then the result of the PDT's hypothesis is that there are somewhere between 0 and 500 UXO items remaining on the site. Using additional information (e.g., no UXO found during field operations, no records/historical UXO finds, no craters or other evidence observed in LIDAR data or during field investigations), the PDT should have a greater certainty that the total amount remaining on the site after site characterization is closer to 0 UXO than it is to 500 UXO items.

8.6.2. MC.

8.6.2.1. For NCMUAs, the PDT should consider the types of munitions used, frequency of use, and area over which the munitions were used to decide whether MC characterization is necessary. In many cases, MC characterization is not required at NCMUAs because the number of munitions expended or discarded at the site is either zero or small and often dispersed over a large area (e.g., training and maneuver area), so that no concentrated sources of MC are present. The CSM should explain what the MC source is believed to be if sampling in NCMUAs is being considered. Figure 8-3 provides an example of decision logic for characterization of MC at NCMUAs.

8.6.2.2. Areas of an MRS confidently determined to not be impacted by munitions use may be useful for estimating non-munitions-related background concentrations of MC analytes (e.g., metals, PAHs, perchlorate). Areas within the same MRS are more likely to have similar soil type and physical characteristics than a more distant reference area.

8.6.2.3. Contingency plans that allow for MC sampling should be discussed in planning documents in the event that post-detonation sampling is required during intrusive operations or if a localized potential source of MC is discovered during the MEC investigation (e.g., remnants of a low-order detonation or a dud round that may have been breached). These results would be added to the site dataset for evaluation during the site risk assessment.

8.7. Characterizing Small Arms Ranges.

8.7.1. Introduction. There has been a considerable amount of study performed at SARs. These studies have focused on where the contamination is likely to be and on how best to measure it. Prior to conducting site characterization or remediation at SARs, review of the following publications is recommended.

a. ITRC Guidance: Characterization and Remediation of Soils at Closed Small Arms Firing Ranges, available at http://www.itrcweb.org/Documents/SMART-1.pdf

b. USEPA Region 2 Guidance: Best Management Practices for Lead at Outdoor Shooting Ranges, available at http://www.epa.gov/region02/waste/leadshot/

c. Technical Review Workgroup (TRW) Recommendations for Performing Human Health Risk Analysis on Small Arms Shooting Ranges (OSWER #9285.7-37), available at http://www.epa.gov/superfund/programs/lead/products/firing.pdf

d. Treatment and Management of Closed or Inactive Small Arms Firing Ranges (ERDC / EL TR-07-06), available at http://el.erdc.usace.army.mil/elpubs/pdf/trel07-6.pdf

8.7.2. MEC. Site characterization goals for SARs typically are restricted to characterizing MC since small arms ammunition is not considered MEC. If, however, there is a potential to find MEC on the site, either from overlapping use or mixed use of the site over time, then the portions of the MRS that have a potential for MEC should be characterized using the approaches outlined in Sections 8.4 through 8.6.

8.7.3. MC. The most prevalent MC at SARs include lead, antimony, copper, and zinc from bullets, bullet fragments, and bullet jackets. Pellets from shotgun shells contain mostly lead but also antimony, arsenic, and other minor constituents, including zinc, copper, nickel, and cadmium. Tungsten also may be an MC at certain SARs (see discussion of tungsten in Chapter 7). Although not MC, PAHs may be present at skeet and trap ranges where clay targets have been used and may need to be addressed in order to close a SAR MRS. Lead, which accounts for more than 85% of the mass of a small arms projectile, is typically the risk driver for MC characterization at SARs due to its documented deleterious health effects on human and ecological receptors.

8.7.3.1. The planning aspects for investigation of a SAR are similar to the planning steps discussed above for medium- and large-caliber MRSs. If the SAR is closed, it is important to obtain information regarding the former range, including the type of range, historical direction of fire, location of firing lines, and location of the target berm, if one was used. The PDT should refer to the Range Operations reports discussed in Chapter 7 for information on standard Army range designs. Figures 8-4a and 8-4b provide example decision logic flow-charts for characterization of SARs.

8.7.3.2. The most common types of military ranges are static ranges, where a stationary shooter fires at a known target, and shotgun ranges (e.g., skeet and trap ranges).

8.7.3.2.1. Static SARs. In many instances, static SARs have impact berms located behind the targets, designed to absorb the impact of the bullets. If an impact berm is known to have been used at a SAR, but it is no longer present at the MRS, then inquiries should be made regarding the disposition of the berm soil. If the berm soil was removed from the MRS, the area that received the soil may need to be included in the site characterization. If the berm soil was spread and graded at the MRS, then the MC investigation design needs to account for a potentially larger area of investigation. Because impact berms may contain high enough lead concentrations to be classified as RCRA hazardous waste, soil from impact berms is often tested using the RCRA Toxicity Characteristic Leaching Procedure (TCLP) in the event that future off-site disposal may be required (see Chapter 10). Leaching potential of soil to be left in place (i.e., not characterized for disposal) may be more appropriately evaluated using the Synthetic Precipitation Leaching Potential (USEPA Method 1312). The PDT should consider the period of time during which a static SAR was in use and the estimated amount of shooting done during that time. If the SAR was heavily used, then there is a possibility that propellant residues may be present at the firing lines, and samples should be collected and analyzed for these residues (see Chapter 7 for a discussion of analytical methods for propellants).

8.7.3.2.2. Shotgun Ranges. The primary characteristic of all shotgun ranges from an environmental perspective is the wide distribution of shot. This results in a relatively large area in which MC (particularly lead) might be distributed. Understanding the firing positions and angles of skeet release is important to be able to delineate the area of maximum shotfall. Vertical distribution of MC in soil typically is limited to the near surface unless the soil in the shotfall area and/or target accumulation area has been reworked. PAHs should be considered for the analytical suite for shotgun ranges if clay pigeons composed of coal tar pitch were utilized as skeet targets. If target fragments are observed, the target accumulation area should be demarcated and compared to the fragment distribution expected based on the specific range configuration. If the observed target fragment accumulation area is within the bounds of the anticipated target fragment accumulation area, then the distribution of target fragments provides initial boundaries for the areas requiring evaluation for PAH presence and, later, delineation, if needed. If the observed target fragment accumulation area is not within the anticipated area or if no target fragments are observed, then the soil in the area may have been reworked. In the case where target fragments are observed outside of the anticipated area, it is recommended that presence/absence sampling (and, later, delineation sampling, if needed) for PAHs be conducted where fragments are observed. During the TPP process, the PDT should consider the history of the MRS with regard to soil removal or other site work to decide whether to sample for PAHs in typical target accumulation areas, even if no clay targets or fragments are observed.

8.7.3.2.3. Heterogeneity on SARs. The PDT should be aware that lead contamination at SARs may present unique challenges with respect to the collection and analysis of representative soil samples. These challenges are related to the distribution of metal contaminants, which can be present as discrete particles ranging in size from intact bullets or shot to bullet fragments. Soil samples from firing ranges are typically a heterogeneous mixture of matrix materials and contaminants. Individual granules of soil can be significant relative to the size of a subsample selected for analysis. Consequently, the analytical results can vary considerably depending on the particular group of granules selected in the subsample. Therefore, sample collection strategies should be site specific and a function of particular metal distribution and soil gradation (see ERDC TR-12-1, Evaluation of Sampling and Sample Preparation Modifications for Soil Containing Metallic Residues, January 2012).

## 8.8. Munitions Constituents Sampling and Analysis.

### 8.8.1. Soil Sampling.

8.8.1.1. Representativeness of Soil Data. Fundamentally, soil sampling is performed to provide a basis for inference about characteristics of the unsampled material. The first requirement for representativeness is that the volume of soil (or population) to be represented must be explicitly delineated; in IS, this is the sampling unit or decision unit. The selected soil sampling and processing methods should yield samples and results that are representative of the unsampled material within the delineated volume of soil. Soil data representativeness is a combined function of precision (i.e., reproducibility) and accuracy (i.e., closeness to the true value). Precision is measured by the difference between results from replicate samples from the same volume of soil. Accuracy cannot be measured because the true mean concentration of the volume of soil cannot be known. A result that is not reproducible within acceptable, specified limits cannot be deemed representative of the larger volume of soil. Replicate measurements and a statistical approach are needed to quantify precision. The required degree of precision should be specified in the DQOs. Non-probabilistic (i.e., judgmental or biased) samples may meet the DQOs but may not be representative.

8.8.1.2. Site Stratification. Site stratification is the process of subdividing a site, study area, or MRS into smaller areas (strata) having similar characteristics that are logical for sampling and analysis. Stratification should be based on both the characteristics identified in the CSM and the project objectives. The purpose of site stratification is to differentiate and define specific, logical component areas of soil to be represented by sample results. Dividing the site into strata optimizes the sampling design by decreasing variability and improving the representativeness of the data within each stratum and by maximizing the relevance of the data to project objectives and the data end use. For instance, for a SAR, a sampling stratum could be defined as the areas where MC release is suspected, such as the target berm and the firing line. A third stratum could be all other areas on the SAR, where MC release is not expected. If the end use of the data is comparison to regulatory or risk-based soil screening levels, the relevance of the strata to the appropriate risk-based exposure units should be considered in sampling design. Site stratification is applicable to all sample collection methods and should be addressed during the systematic planning process and in project planning documents during sampling design.

8.8.1.3. Sampling Methods.

8.8.1.3.1. Discrete or "Grab" Samples. Discrete or grab samples are defined as an aliquot of soil individually collected from one sample location or from a single depth in one borehole, from which a subsample typically is analyzed individually. The reproducibility of results between individual discrete samples is often poor. There may be unacceptably large variability in results between field replicates. A result from a single grab sample should not be considered representative of the material from which it is collected. A set of discrete samples of uniform size and collected in the same manner from a defined area (volume) of soil can form a basis to calculate statistical parameters that provide representative estimates for that volume of soil. Results from a very small set of discrete samples may not be reliable. The number of discrete samples needed depends on the heterogeneity in the distribution of the MC of interest within the sampled area. The VSP software package described in Section 8.3 may be used to assist in planning how many discrete samples should be collected to achieve a certain level of statistical confidence in the results. Outlier sample results should not be discarded simply on the basis of the concentration value; rationale should be provided to defend or explain the decision to discard an outlier sample result.

8.8.1.3.2. Composite Samples. The greatest source of variability (error) in soil sample data results from heterogeneity. Composite sampling reduces sample variability that results from soil heterogeneity. Heterogeneity is present at all scales due to compositional differences between individual soil particles (compositional heterogeneity) and due to the nonuniform distribution of analytes across a site (distributional heterogeneity). Traditional composite sampling reduces distributional heterogeneity by physically averaging the spatial variability and providing an estimate of the mean concentration of an analyte within the sampled volume of soil. For this average to be most relevant to the project objectives and end use of the data, the volume (lateral and vertical extent) of the soil represented by each composite sample should be considered carefully. One characteristic of composite sampling is that information regarding the spatial distribution of analytes within the sampled area is not obtained. Therefore, the volume of soil represented by a composite sample should be small enough that variability (heterogeneity) within that volume is not of concern in the decision process. For instance, a relatively small mass of contaminant within a very small volume of soil (e.g., a discrete sample) can cause elevated MC concentrations (a “hot spot”). However, over an area relevant to the decision to be made, a very small area of elevated concentration may not be significant.

8.8.1.3.2.1. IS uses composite sample collection and laboratory processing methods that address sources of sampling error and variability to obtain an individual aliquot for analysis that contains all constituents in exactly the same proportion as they are present in an explicitly defined volume of soil in the field (i.e., a sampling unit) (ITRC, 2012). The analytical result is an estimate of the mean analyte concentration present in that field sampling unit.

8.8.1.3.2.1.1 Research in the area of secondary explosives contamination at ranges has supported the use of IS rather than discrete or “grab” sampling (see various CRREL technical report [TR] series publications). USEPA SW 846 Method 8330B, one of very few USEPA methods to recommend field sampling procedures, recommends the use of IS for field collection and laboratory processing of samples for explosives. As the familiarity and regulatory acceptance of SW8330B increase, this method is expected to become the standard for evaluating secondary explosives contamination at ranges. For many projects, IS provides the data quality needed to satisfy the project objectives more effectively than traditional grab sampling. When adapting IS for a specific site investigation, the PDT needs to ensure that all aspects of the sampling and processing design are defined to meet project goals for each chemical of concern and sampling objective.

8.8.1.3.2.1.2 The use of IS currently is not mandated at the guidance level. During the acquisition process, the USACE PDT should make an initial evaluation regarding its use, considering factors such as regulatory acceptance of IS, the lack of published IS laboratory sample processing methods for analytes other than explosives, and the availability of accredited commercial laboratory services, to determine if IS is the best method for the project. If the USACE PDT determines that IS is the best choice, the SOW/ PWS should specify its use. For performance-based contracts, the contractor may recommend an alternate approach during the proposal phase for government consideration. During TPP, as the project's DQOs are established, if it is concluded that the initial determination should be changed (i.e., IS is selected when discrete is in the SOW/PWS or vice versa), contracting personnel should be consulted for direction. If IS is determined to be required, the PDT should include personnel knowledgeable and experienced in the design of IS. Sources of published guidance for IS include Technical Guidance Manual for the Implementation of the Hawai’i State Contingency Plan (http://www.hawaiidoh.org/tgm.aspx); Draft Guidance on Multi-Increment Soil Sampling, Alaska Department of Environmental Conservation (http://www.dec.state.ak.us/spar/csp/guidance/multi_increment.pdf); and the ITRC Incremental Sampling Methodology guidance document (http://www.itrcweb.org/teampublic_ISM.asp).

8.8.1.3.2.1.3 A sampling unit (sometimes termed decision unit) is the area and depth of soil (i.e., the sampled population) to be represented by the sampling process. Sampling units must be delineated so that the mean analyte concentrations obtained are directly relevant to well-defined project objectives. Because IS provides an estimate of only the mean concentration of an analyte within a specific volume of soil that is represented by a single incremental sample (the sampling unit), the size and configuration of the sampling unit are critically important in determining the relevance of the data to its intended end use. Sampling unit size depends on the project's objectives (i.e., the end use of the data and the DQOs) and the CSM (the release mechanism and extent of contamination as well as the possible redistribution of contaminants). Based on these considerations, the sampling unit should be no larger than the size at which heterogeneity (i.e., "hot spots") within the unit is not a concern.

8.8.1.3.2.1.4 For sampling during SIs, where the objective is to identify areas suspected or potentially having contaminants at levels of concern, the objectives may be met with a higher degree of confidence by using a hybrid sampling approach, combining probabilistic IS within appropriately sized sampling units located on the basis of non-probabilistic professional judgment. Because IS can cost-effectively provide more thorough coverage than discrete sampling of areas identified as most likely to contain contamination at levels of concern, the method is less likely than discrete sampling to miss any significant contamination within a sampling unit. When determining the locations of sampling units, consideration should be given not only to likely initial release mechanisms and contaminant distribution but also to how post-release processes or disturbance may have changed the spatial distribution of analytes.

8.8.1.3.2.1.5 For RI objectives, the nature and extent of contamination must be determined. Unless the site being studied has been sufficiently characterized or there is other evidence that indicates that the site is not contaminated, probabilistic sampling strategies in multiple sampling units may be required. Sampling objectives (e.g., based on current or future site use) will need to be considered to determine the required number, size, and geometry of sampling units to provide adequate coverage and spatial resolution.

8.8.1.3.2.1.6 Field sampling procedures that distinguish IS from conventional composite sampling include the following:

- Collecting increments from a single sampling unit (population) specifically delineated to meet a project objective.

- Collecting a sufficiently large number of increments (typically 30 to 100) to address the distributional heterogeneity of analytes.

- Ensuring that the increments are of equal mass.

- Ensuring that the increments are collected from throughout the entire sampling unit in an unbiased manner.

- Collecting an adequate total sample mass (typically 1 to 2 kilograms dry weight) to overcome effects of compositional heterogeneity due to the inherent particulate nature of soil and sediment.

8.8.1.3.2.1.7 Laboratory processing and subsampling procedures that enhance representativeness include (for non-volatile analytes):

- air drying of the entire field sample (for ease of handling);
- reducing particle size by grinding, depending on target analytes and DQOs; and
- multi-increment laboratory subsampling from the entire process sample to obtain an aliquot for analysis having sufficient mass to control variability due to compositional heterogeneity.

8.8.1.3.2.1.8 If a PAH is an analyte of interest at an MRS where IS will be used, then the following sample preparation procedure is recommended:

- Dry the sample to constant weight.
- Sieve the sample with a 2 mm sieve (#10 mesh).
- Mortar and pestle any dirt clods / clay target chunks that do not pass the sieve.
- Consider advantages and limitations of milling based on project-specific data and quality needs, the specific PAH compounds, and their form.
- Using an incremental approach, collect at least 30 increments from the processed field sample to obtain a laboratory sub-sample of 10 to 30 g for extraction and analysis.

8.8.1.3.2.1.9 Additional parameters to consider include the field sampling scheme, degree of sample processing, vegetation inclusion/exclusion, and sieve sizes (sieve sizes are of interest only if a particular particle size fraction is the population of interest). Refer to published IS guidance for details regarding these considerations. The PDT, contractor (if applicable), laboratory, and applicable regulatory agencies must discuss the selected field and laboratory procedures to ensure acceptance of data to the data users. The regulatory acceptance should be documented to ensure future acceptance of the data.

8.8.1.4. Considerations for Soil Sampling Method Variation Across Site Investigation Phases. The selected soil sampling method should be the most appropriate to meet the investigation objectives for each phase of site investigation (e.g., SI, RI). However, due to the fundamental differences in nature between discrete and IS sampling and their statistical properties, the different types of data generally should not be combined. Statistical integration or direct quantitative comparison of discrete and IS data is problematic. Use of a single sampling method would facilitate direct comparison of the data.

8.8.1.5. Soil Background Determination.

8.8.1.5.1. If the PDT determines that background sampling is required, it should select sampling locations with care. The areas selected for background sampling should have a soil type and composition similar to that of site samples and be as close as reasonably possible to site samples but unaffected by munitions activities. Background sample locations also should be selected with consideration for nonmunitions-related activities that may have released analytes of interest in background sampling areas (e.g., lead or PAHs along roadways).

8.8.1.5.2. Defining a single value as a background concentration for a particular analyte normally is not feasible, so background concentrations should be expressed as ranges based on a statistical analysis of the background sampling data. The range of uncertainty needs to be well defined, particularly when field sample concentrations from the project site are close to the background mean concentration values. The number of background samples collected should be sufficient to be statistically relevant. If IS is used, the site and background sampling units ideally should be of approximately the same size

8.8.1.5.2.1. Site-to-background comparisons may use statistical methods, including parametric and nonparametric statistical tests (see ER 200-1-16, Environmental Statistics Guidance). VSP has modules that support these site-to-background comparisons using parametric, nonparametric, and IS sampling approaches. An experienced environmental statistician should be consulted regarding selection of appropriate statistical methods.

8.8.1.5.2.2. A geochemical correlation may be performed to compare site-to-background concentrations. The basis of this technique is that soils tend to contain trace element metals and major element metals in relatively constant proportions in a given area. Comparisons of the concentrations or concentration ratios between reference metals (e.g., iron, aluminum, manganese) and metals MC (e.g., lead, copper, antimony) are performed. If the metals concentrations show a high degree of correlation, then samples having concentration that do not fit the observed strong correlation (i.e., higher ratio of MC metal to reference metal) are likely to represent MC contamination. Reference metals that are selected should be abundant, commonly present in soil, and not considered MC of interest at the project site. Secondary comparisons between MC metals constituents can also be a line of evidence indicating contamination. For example, copper/lead or zinc/lead ratios in uncontaminated samples would be different than in samples co-contaminated with these metals.

8.8.1.5.2.3. Graphical representations may be useful for site-to-background comparison. Histograms, box plots, and correlation diagrams may be used to graphically analyze differences in background and site MC concentrations to determine if the site samples are contaminated.

8.8.1.5.3. IS is well suited to determine accurate, site-specific mean background concentrations. At least one of the sampling units should be sampled in triplicate, and the PDT should consider collecting triplicates for all background sampling units to provide a measure of uncertainty in the estimated background mean. Background sampling units should capture the natural variability of soil composition across the area of interest. More than one sampling unit may be required to capture this natural variability. The configuration and location of background sampling units and the number of replicate samples to be collected should be based upon the DQOs established by the PDT as part of the TPP process. Ideally, background sampling units should be equal in size and increment density to field sampling units. However, background analytes may tend to have a more uniform spatial distribution than MC released from site activities. This may allow sufficiently accurate estimates from smaller sampling units or from fewer increments.

8.8.2. Sediment and Surface Water Sampling.

8.8.2.1. Surface Water Sampling Considerations.

8.8.2.1.1. MC contamination in surface water derives from surface water runoff from contaminated areas and leaching. Groundwater discharge to surface water as gaining streams, seeps, and springs also may introduce MC to surface water, particularly for sites with shallow groundwater or in particular types of geology (e.g., karst).

8.8.2.1.2. Surface water sampling for MC must be accompanied by a thorough documentation of the characteristics of the surface water body, such as size and shape, depth, flow rate (if applicable), pH, temperature, conductivity, dissolved oxygen, and turbidity. These characteristics affect the capacity of the water to carry MC contaminants, contaminant partitioning/speciation, and bioavailability.

8.8.2.1.3. Samples of surface water may be grab samples, which are discrete, instantaneous events, or composite samples. Composite samples may be time-weighted, flow-proportional, or depth composites. If the data are to be used in a compliance program, the PDT should refer to state and/or federal regulations for definition and requirements of grab and composite samples (i.e., criteria maximum concentrations for brief exposures and criterion continuous concentrations for longer exposures).

8.8.2.1.4. For MC characterization, surface water samples should be collected upstream of the inferred location of contaminant entry into the surface water body (i.e., reference or background location), at or just downstream of the inferred location or area of contaminant entry, and downstream of the point of contaminant entry to determine the extent of MC contamination.

8.8.2.1.5. The timing of the sample collection may influence the MC concentration and should be considered carefully by the PDT. Low flow seasonal conditions, high flow seasonal conditions, and storm events may need to be included in the sampling design. Areas of tidal influence should consider time-composite samples and/or grab samples collected at varied tidal stages.

8.8.2.1.6. For storm water runoff sampling designed to obtain qualitative and quantitative data to assess episodic migration of contaminants, refer to USEPA 833-B92-001 for storm water sampling guidance (http://www.epa.gov/npdes/pubs/owm0093.pdf).

8.8.2.1.7. Freshwater metals criteria for certain metals (including lead, copper, and zinc) are hardness-dependent. The ecological risk screening criteria for these metals are relatively low and decrease with decreasing hardness of the water. Determining adequate reporting limits for metals in surface water requires an assessment of water hardness, the calculation of the consequent hardness-dependent comparison criterion for each metal, and the derivation of the resulting ideal and acceptable detection limit for each metal. For surface waters with low hardness and resulting low ecological risk screening criteria, it may be necessary to use the "clean hands / dirty hands" sample collection method (refer to USEPA Method 1669, Sampling

Ambient Water for Trace Metals at USEPA Water Quality Criteria Levels (http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=200034VZ.txt) and a trace metals laboratory analysis (e.g., USEPA Method 1638).

8.8.2.1.8. A variety of equipment is available for surface water grab sampling depending on whether samples are to be collected from the surface (e.g., sample bottle submersion, dipper/pond sampler) or from within the water column (e.g., peristaltic pump, Kemmerer sampler, bomb sampler, semipermeable membrane device). Composite sampling using a programmable Isco-type sampler allows for adjusting the period of the sample and the increment frequency and volume.

8.8.2.2. Sediment Sampling Considerations.

8.8.2.2.1. When designing a sediment sampling plan for stream sediments, the PDT should consider collecting a set of samples (or an IS) from unbiased locations to provide the most representative results. A minimum "reach" or length of stream for sampling is considered to be five to seven times the stream width. Unbiased discrete point sampling or unbiased sampling along randomly spaced transects help to avoid bias.

8.8.2.2.2. Sediment sampling poses challenges with respect to sample collection and analysis. Challenges associated with sample collection include cross contamination, ability to recover all particle size fractions, and excessive water in the sample. Analytical challenges include the low reporting limits required for comparison to ecological risk screening values and matrix interference.

8.8.2.2.3. Sediment samples often are co-located with surface water samples. Surface water should be sampled before collecting a sediment sample. Sediment should be sampled from the downstream side of the surface water body. Liquid should not be decanted; however, excess water should be avoided. Prior to sampling and during TPP, the PDT should coordinate with the analytical laboratory to discuss protocols for analyzing sediment samples that have a high water content. Some considerations for watery samples include whether the water will be discarded or processed, whether the water will be decanted or evaporated, and whether the water removed will be considered part of a dry weight calculation. The impact of salinity on analytical methods should also be addressed, if applicable.

8.8.2.2.4. Sediment grab samples may be collected with a variety of tools, including trowels and "clam shell" type samplers, which can introduce bias into the sampling for a variety of reasons, and vertical cylinder-type samplers, piston corers, and gravity corers, which are less prone to bias. Factors that influence sampling equipment selection include physical characteristics of the sediment bed; width, depth, and flow rate of the surface water; the need to minimize sample disturbance and washing; and the need for an undisturbed sample.

8.8.2.2.5. In addition to analyzing for MC, simple bulk chemistry parameters (e.g., total organic carbon) may be analyzed to assist with evaluation of MC fate and transport. The acid volatile sulfide (AVS) concentration in sediment is a key factor in evaluating metals bioavailability. Sulfide binds cationic metals, forming relatively insoluble complexes that are minimally bioavailable. USEPA guidance on assessing the toxicity of metals mixtures in sediment to benthic organisms indicates that when the sum ($\sum$) of the molar concentrations of simultaneously extracted metals (SEM) minus the molar concentration of AVS is less than zero, no toxicity should occur. For additional guidance regarding the use of AVS-SEM data for evaluating metals toxicity in sediment, refer to Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver and Zinc) EPA/600/R-02/011 January 2005 (http://www.epa.gov/nheerl/download_files/publications/metalsESB_022405.pdf).

8.8.3. Groundwater Sampling.

8.8.3.1. Groundwater is potentially a major transport pathway for MC and migration of MC to groundwater can greatly expand the extent of MC contamination and lead to potential exposure risks to off-site receptors.

8.8.3.2. Generally, existing water wells are not suitable for characterizing groundwater because of nonoptimal location with respect to possible MC sources and because they are designed for water production not sampling and characterization of contaminant plumes.

8.8.3.3. Dedicated groundwater monitoring wells are likely to be much more useful for site characterization purposes because of their design and location. Refer to EM 200-1-17, Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites (http://publications.usace.army.mil/publications/eng-manuals/EM_1110-1-4000_sec/toc.htm). Monitoring wells can be installed using conventional drilling technology, including hollow-stem auger, rotary drilling (drilling fluid or air), and sonic methods.

8.8.3.4. Direct push wells also can be used for groundwater sample collection and are installed by pushing or hammering rods to depth. This method is advantageous for cost reasons because it produces little waste material and because a borehole is not created; however, it is not applicable in certain situations (e.g., hard, consolidated formations or presence of cobbles). Refer to The Use of Direct-Push Well Technology for Long-Term Environmental Monitoring in Groundwater Investigations, ITRC (www.itrcweb.org).

8.8.3.5. Groundwater sampling methods (both active and passive) are the same as those described in guidance for HTRW sites.

8.8.3.6. Groundwater is a dynamic system; however, concentrations of analytes in background (up gradient) wells should be stable over time. Trends, shifts, or cyclical patterns should be investigated. In order to determine mean background concentrations for groundwater analytes, it is recommended that a minimum of four sampling events be performed over 1 year; 8 to 10 observations are preferable to increase statistical certainty. If well-documented background concentrations in groundwater are higher than MC screening levels, then it is recommended that alternate site-specific standards be developed.

8.8.4. CA Sampling Considerations.

8.8.4.1. The initial planning and investigation steps for a CWM site are very similar to those described in this manual for conventional munitions. Therefore, this section focuses on the procedures and requirements that are unique to CWM characterization.

8.8.4.2. CWM DC provides specialized support to assist HQUSACE, USACE Commands, FOA, and laboratories by executing CW activities and maintaining state-of-the-art technical expertise for all aspects of CWM DC response activities. The CWM DC is the only DC authorized to execute any phase of a CWM project.

8.8.4.3. In general, CWM sites are comprised of disposal pits and test trenches and, to a lesser extent, impact ranges. The purpose of CWM site characterization is to obtain surface and subsurface sample data to adequately characterize the site IAW DQOs.

8.8.4.4. Air monitoring for CA is required whenever there is a risk for worker or public exposure to CA during or due to site operations. An air monitoring plan must be developed and included as a supporting plan to establish the policies, objectives, procedures, and responsibilities for the execution of a site-specific monitoring program. DA PAM 385-61 requires that a monitoring plan be developed in writing and implemented. DASA-ESOH Interim Guidance for Chemical Warfare Materiel Responses, 1 Apr 2009, provides additional guidance for air monitoring at CWM sites.

8.8.4.5. Sampling and analysis for CA and associated ABPs are used to determine if residual CA contamination from a release, spill, or disposal operation is present and to determine if other hazardous chemicals or MC are mixed with the chemical agent of concern. Because some types of CA are not persistent in certain types of environments or after a certain amount of time, the PDT should take the persistence of the suspected chemical agent into consideration during site planning (see Chapter 7).

8.8.4.6. Environmental samples may consist of soils and other solids, water, sludge, and vegetation. Each environmental sample collected is homogenized and then divided into a minimum of three split samples prior to monitoring or analysis. Prior to off-site shipment, the headspace of one of the split samples is screened for CA using airborne methods to ensure that concentrations are below the airborne exposure limit (AEL). If the headspace is over the AEL, the samples must be stored on site for decontamination and disposal without further analysis. If CA concentrations are determined to be below the AEL, then the second split sample may be shipped off site to a CA laboratory to perform total analyses for CA/ABP (see requirements for CA laboratories in Chapter 7). The results of the second split must be nondetect prior to release of the third split to a commercial laboratory for traditional environmental analyses. This procedure ensures that a non-CA lab is not contaminated accidentally with CA-containing samples.

8.8.4.7. Environmental samples should be collected immediately beneath and/or adjacent to any CWM. Samples of surrounding media should also be collected whenever there are visual or airborne indicators of potential CA contamination. Historical information also should be used to determine sampling locations.

8.8.4.8. All samples potentially containing CA must be sent to a government or contractor laboratory with a current bailment agreement for analysis or be cleared as having no detectable levels of agent by extraction-based analytical methods prior to being sent to an HTRW lab.

8.8.4.9. It is not recommended that IS be conducted when collecting samples for agent and ABP analysis. Although in some projects, composite samples may be collected from test pits or trenches, sample processing methods typically associated with IS (drying, sieving, and milling/grinding) are not recommended. This recommendation is primarily due to the increased potential for exposure of laboratory personnel to CAs (particularly if they were to be air dried, unless all were air dried in an area where the air could be captured and scrubbed) as well as the potential for analyte loss. Additionally, air drying would likely make the process to quickly clear samples for release to traditional laboratories impossible and, thus, holding times for other analytes would not be met.

8.8.4.10. IDW generated at a CWM site must be handled IAW the procedures described in DASA-ESOH Interim Guidance for Chemical Warfare Materiel Responses, 1 Apr 2009, which are summarized in Figure 8-17, below. Additional requirements may also apply (e.g., RCRA treatment standards).

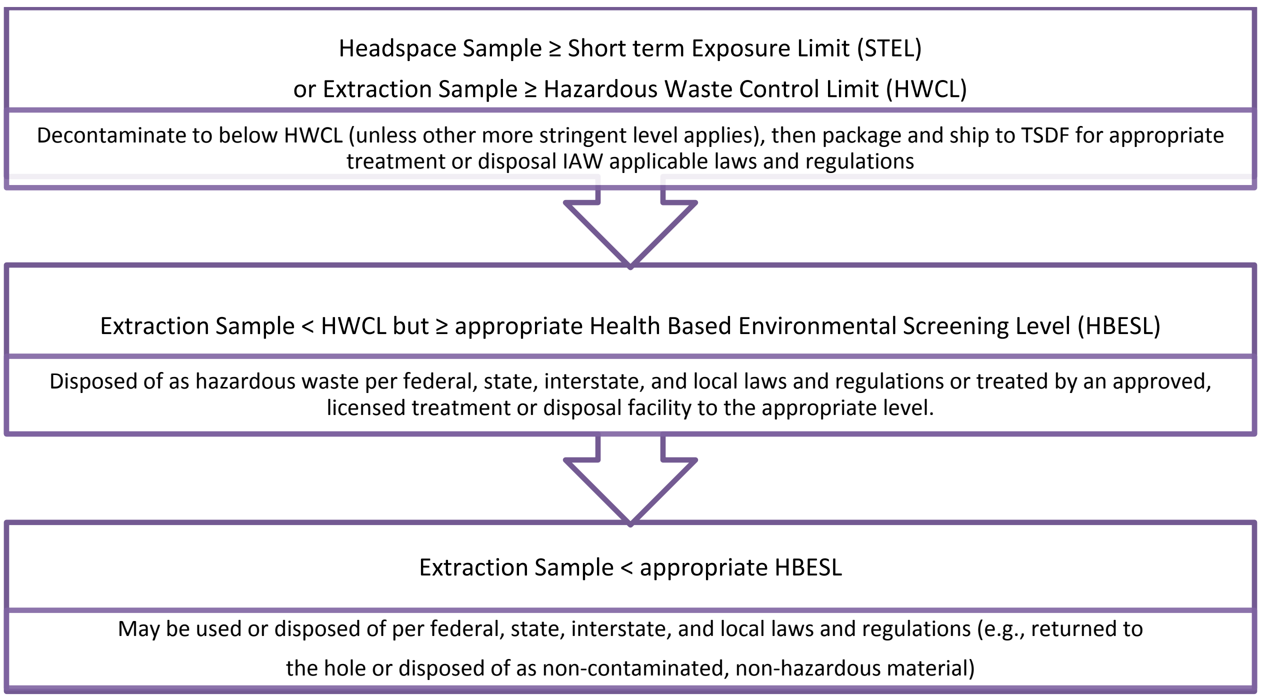



Figure 8-17: Waste disposal procedures for CA-contaminated media (DASA-ESOH Interim Guidance for Chemical Warfare Materiel Responses, 1 Apr 2009)
Note: Laboratory limits of quantitation must be below appropriate HBESL.

8.8.5. CAIS Kits.

8.8.5.1. Numerous types of CAIS kits were produced and used by all branches of the military between the 1930s and 1960s to train military personnel on the identification of chemical agents (U.S. Army, 1995). Most of these kits are believed to have been used during training exercises, and the known kits that were not used were destroyed during the 1970s and 1980s. However, some may remain in the subsurface at some MRSs.

8.8.5.2. In general, CAIS kits contained dilute amounts of CA stored in glass vials or ampules, which were in turn stored within metal or wood "pigs" used for storage and transportation of the CAIS kits. Some CAIS kits (K945) were contained within a plastic carrying case. Although the metal detectors discussed in Chapter 6 of this EM are not capable of detecting individual glass vials, glass ampules, wooden pigs, or plastic carrying cases, they can detect metal pigs and the metallic bands surrounding wooden pigs in which the glass vials were stored. GPR may be capable of detecting individual glass vials or tubes, as well as plastic carrying cases; however, a study performed by the USACE at the Former Spring Valley FUDS in 2004 demonstrated that detection rates for simulated CAIS vials and ampoules ranged from 11% (at 2.5 to 3 feet deep) to 42% (0.5 to 1 feet deep). This study also reported false alarm rates (anomalies interpreted as potential glass items but known not to be) of between 9,000 and 15,280 anomalies per acre. Note that GPR surveys designed to detect glass vials or ampoules across an entire MRS would be very expensive. The PDT should evaluate all data sources (e.g., historical documents and interviews, geophysical transect surveys) to determine the most likely type of CAIS used at a site, the packaging container types that were used for these kits, and the potential location(s) of CAIS training within the MRS. The PDT also must factor for variable detection rates and potentially high false positive rates of the various technologies available to detect CAIS kits and individual vials or ampoules.

8.8.6. Characterization of Underwater MRSs.

8.8.6.1. Underwater MRSs can be former live-fire testing and training ranges that used surface munitions (e.g., bombs, artillery projectiles) or subsurface munitions (e.g., mines, torpedoes); defensive sites (e.g., forts, coastal artillery batteries); accident sites; disposal sites; or sites where munitions were jettisoned (e.g., during an emergency).

8.8.6.2. Underwater MRSs may pose either acute or chronic impacts. Acute impacts include explosion, fire, or chemical exposure resulting from functioning of a munition (e.g., detonation) or failure of a munitions' component (e.g., a casing body) that released its contents (e.g., CA). Chronic impacts include adverse health effects resulting from long-term exposure to a substance (i.e., MC) or persistent adverse health effects from an acute exposure.

8.8.6.3. The factors that influence MC release from munitions in a water environment include current speed; MC dissolution rate; MC saturation concentration; MC cavity radius inside the munitions; the hydrodynamic mixing coefficient; and the breach hole shape, size, and orientation. Corrosion of the munition, which generally is accelerated in salt water, may affect the timing and rate of release of MC from the munitions and the stability of the munition. It is important to understand that the period of maximum release of MC may not occur until decades after MEC were deposited in the water (i.e., after a long period of corrosive attack).

8.8.6.4. When sampling surface water at an underwater MRS, the PDT needs to consider possible upstream sources of contamination. The timing of sample collection must be considered based on wet versus dry weather, flood events, and other factors that may influence the ability to collect samples and the concentration of MC. The effects of salinity on the sampling and analytical methodology should be considered if the underwater MRS is in a brackish or marine environment. If a munition is located underwater, surface water sampling proximate to the munition may be appropriate; however, if this is anticipated, procedures should be considered and sampling documented carefully in order to ensure that the sample that is collected is representative of the water concentration rather than cross contamination from the munition itself.

8.8.6.5. When sampling sediment, start downstream and move progressively closer to suspected MC source areas. Collect water samples before collecting sediment samples to avoid sediment resuspension. In tidal waters, although water and sediment may move in multiple directions, there typically is a predominant component to current direction, and it is recommended that sediment sampling be performed along the axis of predominant current direction. Sediment deposition and erosion rates and patterns must be considered in the sampling design; these parameters influence the depth of munitions items and potential MC transport and exposure pathways. Human and/or ecological receptors of interest should be identified, and the sampling design should be guided by the CSM for receptor interactions with potential MC in sediment. For instance, if benthic fauna are the only receptors of interest, then it may be acceptable to limit sample collection to shallow sediment. The effects of salinity on the analytical methodology should be considered if the underwater MRS is in a brackish or marine environment.

8.8.6.6. If the ERA scenario leads to quantitative evaluation of biota, the PDT should proceed carefully. The quality of biota analyses typically is poor due to high levels of interference. Only MS methods should be used for biota analysis, and only experienced laboratories should be selected for biota analyses. Sampling strategies for biota should carefully consider whether to sample individuals vs. compositing within the species based upon the objectives of the sampling. Multiple species compositing is not recommended.

8.8.6.7. Characterization of underwater MRSs is a topic of active research. The Hawai‘i Undersea Military Munitions Assessment (HUMMA) project included a substantial research effort with the objectives of (a) developing a cost efficient and effective survey and assessment strategy for evaluating whether sea-disposed military munitions have had or have the potential to significantly impact human health and the environment and (b) testing the survey and assessment strategy at a single site. HUMMA project documents are available at http://www.hummaproject.com/project.php. Although sea-disposed munitions are not classified as MRSs, the technology developed may be applicable at underwater MRSs. This topic is also a research initiative for SERDP and ESTCP, which have published several reports available at http://www.serdp.org/Featured-Initiatives/Munitions-Response-Initiatives/Munitions-in-the-Underwater-Environment. Three issues of the Marine Technology Society Journal have also been devoted to the subject, "Legacy Underwater Munitions: Assessment, Evaluation of Impacts, and Potential Response Technologies" Part 1, November/December 2011, Vol. 45, No. 6 and Part 2, January/February 2012, Vol. 46, No. 1 and "The Legacy of Underwater Munitions Worldwide: Policy and the Science of Assessment, Impacts and Potential Responses," Fall 2009, Vol. 43, No. 4.

8.8.7. MC Considerations Related to MEC Operations.

8.8.7.1. MC sampling representativeness, spatial data, and overall waste disposal requirements are influenced by the choice of MEC removal and disposal technologies.

8.8.7.2. MEC removal technology options include hand excavation, mechanically assisted removal using excavating equipment, remotely operated equipment, armored excavation and transportation, and mechanized soil processing (screens/conveyors/magnets).

8.8.7.2.1. Hand excavation of MEC is the industry standard and provides the best access to soil for sampling and for visibility of potential MC sources. Mechanically assisted removal using excavation equipment may be used in conjunction with hand excavation and offers no additional advantages for MC sampling.

8.8.7.2.2. Armored excavation and transport focuses on larger excavations. Potential MC sources would lose some spatial identity, complicating selection of specific sample locations and depths. Similar issues would apply for MC sampling at sites where remotely operated removal equipment are selected (remotely operated equipment is limited to research and development at this time).

8.8.7.2.3. Mechanized soil processing equipment separates ordnance (or bullets being recovered for lead recycling) from soil. Soil that has been processed no longer has spatial identity because post-processed soil would be placed in piles generated during processing. The soil also is somewhat mixed by the process.

8.8.7.2.4. Intrusive MEC removal efforts frequently require engineering controls, which must be considered in sampling strategies. Barricades limit access to soil that might be available to sample, but their use is required to protect nearby activities from unintentional detonations. Spatial limitations may provide less bias than restricting samples to areas outside the exclusion zone (limiting samples to strictly those collected with anomaly avoidance).

8.8.7.3. MEC disposal technology options include BIP, consolidated shot, laser initiation, and CDC.

8.8.7.3.1. BIP detonations occasionally are required during site characterization efforts that require ordnance disposal (more likely at the RI/FS or EE/CA stage during intrusive operations than during an SI) and during RAs or removal actions. Intact rounds that are BIP typically leave less residue than rounds that experienced a low-order detonation but greater contamination than if the round had functioned as designed with high-order detonation (see ERDC/CRREL TR-06-13, Comparison of Explosives Residues from the Blow-in-Place Detonation of 155-mm High Explosive Projectiles). In addition, BIP of low-order detonated munitions may produce significant explosives residue (see Explosive Residues from Low-Order Detonations of Heavy Artillery and Mortar Rounds, Pennington et al., Soil and Sediment Contamination: An International Journal, 17:5, 533-546).

8.8.7.3.2. The purpose of collecting samples at a demolition site is to assess whether the demolition activities are contributing MC contamination to the site. Sampling and analysis needs should be based on MEC fill, if known, along with composition of the donor charge.

8.8.7.3.3. Predetonation soil sampling is not recommended because the detonation itself unalterably destroys the predetonation site conditions. Post-detonation soil samples should be collected at the location of each specific type of MEC destroyed. Soil sample results should be added to the site dataset for evaluation during the site risk assessment.

8.8.7.3.4. Post-detonation samples should be incremental samples unless there are state or local requirements to the contrary. The sample unit(s) size should be sufficient to determine the average concentration over the area affected by the detonation or the exposure unit of a potential receptor.

8.8.7.3.5. Sand bags are a common means of controlling BIPs. If sand bags are required, the potential implications of ruptured sand bags on post-detonation MC sampling should be considered. For instance, dispersion of the sand from ruptured sand bags can assist in determination of where to sample post-detonation.

8.8.7.4. Consolidated shots involve the detonation of multiple rounds of munitions that were deemed safe to move and detonate together. MC results at consolidated shot areas are analogous to those found at open detonation areas.

8.8.7.5. Laser initiation involves portable, vehicle-mounted lasers that may be used to heat surface MEC and induce detonation. Laser initiation processes are still in the developmental stage. One advantage of laser systems is that they do not require donor charges. However, a study performed by the USACE, Huntsville District shows that MC release was higher from laser initiation than from C4 donor charge for low-order as well as many high-order detonations. Secondary waste stream and sampling needs are similar to those described for BIPs.

8.8.7.6. CDCs are used to destroy MEC while containing both the blast effects and the secondary waste stream within the closed system.

8.8.7.6.1. CDC use is limited to items that are within the NEW that the system is approved to destroy and that contain fill that the unit is approved to destroy. This includes conventional munitions that contain energetics, WP, riot agents, propellants, and smoke. PWP is not approved for disposal in a CDC. Single-site approval has been granted for chemical munitions. Air handling and filtration may be required depending on the munitions being detonated.

8.8.7.6.2. Secondary waste streams must be characterized and disposed of properly. They typically include pea gravel, Torit® filter dust, and decontamination water. Appropriate plans need to be in place for the cost and schedule impacts associated with manifesting and disposal of secondary wastes. For instance, the pea gravel may be classified as hazardous waste (USEPA Hazardous Waste Codes D008 for lead, D006 for cadmium, and/or D003 for reactive waste, such as WP). Filters may be classified as D002 (corrosivity), and the decontamination water may contain lead at hazardous levels.

8.8.8. <u>MC Data Interpretation and Validation</u>.

8.8.8.1. <u>Data Interpretation</u>. After a project property undergoes sampling and analysis, it is necessary to carefully interpret all data and determine if project objectives have been met. Project-related information, such as possible MEC composition (if available) and donor explosive composition, should be provided as part of data interpretation. If numeric project screening levels or action levels have been identified for the project, a comparison of the site data to those levels must take place. Environmental Data Management System software is available to USACE personnel and contractors to aid in this comparison. Data gaps may exist and should be identified and explained. Data gaps may require additional action as part of the remedial response.

8.8.8.2. Data Review. The contractor should perform data review according to their approved UFP-QAPP requirements. Review procedures should be based on EM 200-1-10, Guidance for Evaluating Performance-Based Chemical Data (http://publications.usace.army.mil/publications/eng-manuals/EM_200-1-10/toc.htm); the latest versions of the USEPA Contract Laboratory Program (CLP) National Functional Guidelines (available at http://www.epa.gov/oerrpage/superfund/programs/clp/guidance.htm); the latest version of the DoD QSM; and any applicable state or regional requirements. Although the USEPA National Functional Guidelines were developed for the Superfund CLP, outlier data resulting from SW 846 methods analyses are qualified according to the protocols in the USEPA National Functional Guidelines as there are no comparable procedures published elsewhere. During TPP, the amount of review should be coordinated with regulatory agencies. The review should be documented in the draft and final engineering reports. Review documentation should address review of laboratory and field QC results. Any data validation "flags" must be captured in electronic data submittals. Electronic data should be labeled IAW EPA-540-R-08-005, Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use. Persons performing the data validation should have appropriate experience as determined by their contractual requirements.

8.9. Munitions Response Site Delineation.

8.9.1. Once site characterization activities are completed, the PDT determines if there is a requirement to realign or delineate the MRA or MRS. Realignment is the process of restructuring the data in the appropriate database of record (e.g., FUDSMIS for FUDS properties) (USACE, 2011). Realignment ensures that each MRS is part of an MRA and is equivalent to a MR project. Delineation refers to the process of revising MR projects/MRSs by splitting or further defining MRSs at previously identified MRAs as necessary for more efficient project management (USACE, 2011). Reasons for undertaking delineation include, but are not limited to, the need to address issues such as the anticipated response scenarios, stakeholder input, risk management, and project complexity.

8.9.2. The USACE FUDS Handbook on Realignment, Delineation, and MRS Prioritization Protocol Implementation (2011) provides guidance on realignment and delineation procedures, as well as MRSPP implementation. While the handbook's applicability is for FUDS projects, the guidance outlined within it may be extended to non-FUDS projects. For example, the rationale for MRS delineation may be based on anticipated response action for the MRS regardless of whether or not the MRS falls within the FUDS program.

# CHAPTER 9

## Planning Strategies for Remedial or Removal Actions

9.1. Introduction.

9.1.1. Planning for MR actions requires that a strategy be developed to efficiently and effectively meet project needs. Developing the strategy is a collaborative effort of all PDT members. The strategy should define the goals and RAOs of the actions as well as the means (i.e. processes and technologies) to accomplish the goals and RAOs. Examples of RAOs for MR actions are: 1) "…based on the RI findings, UXO has been confirmed to a depth of 3 feet below ground surface. The RAO is to reduce the potential for human interaction with UXO during recreational activities which currently include surface use and subsurface use to a depth of 1 foot"; 2) "…prevent human ingestion of groundwater with lead concentration exceeding 15 parts per billion…"

9.1.2. The primary methods for accomplishing MR actions include mass excavation and sifting of soil to remove munitions from the MRS, geophysical investigations followed by intrusive investigation to remove the source of anomalies, or some combination of the two. The processes used for response actions that use geophysical investigations are very similar to those used for characterization, but the critical goals and needs are specific to detecting and removing UXO and DMM or just removing UXO and DMM (in the case of mass excavation and sifting operations). The project decisions for MR actions are focused on clearly demonstrating those goals and needs were met.

9.1.3. This chapter focuses on planning strategies for geophysical and mass excavation planning strategies for MR actions. These discussions include site preparation considerations (e.g., vegetation removal, surface removal) and anomaly classification strategies. If new or innovative technologies or robotic technologies are used for a MR action, the PDT also must consider whether there are additional planning considerations that are specific to the implementation of these technologies that are not already contained herein. When considering new technologies, the PDT must determine the goals and objectives for the MR action as well as the best methods to obtain and verify that these objectives were met. PDTs can use the additional guidance found in the below documents to plan remedial or removal action. These guidance documents are mentioned to augment this guidance not to replace or to supersede the guidance that is presented herein.

9.1.3.1. Munitions Response Technologies (SERDP/ESTCP/ITRC, 2006) provides a general survey on site preparation, geophysical, and excavation and removal technologies and can be downloaded from http://www.itrcweb.org/guidancedocument.asp?TID=19. In specific, Chapter 2 discusses vegetation and surface removal technologies; Chapter 3 discusses geophysical detection and positioning technologies; Chapter 9 reviews removal technologies; and Chapter 10 discusses detonation and decontamination technologies.

9.1.3.2. Quality Considerations for Munitions Response Projects (ITRC, 2008) provides a general overview of factors that PDTs should consider as a part of their QC program and can be downloaded from http://www.itrcweb.org/guidancedocument.asp?TID=19. Although the document focuses on QC considerations, Chapter 3 contains key planning considerations for vegetation removal, surface removal, geophysical investigations, anomaly resolution, and verification sampling.

9.1.3.3. Worksheets 10–12 of the Navy's MEC UFP-QAPP template include discussions of the project planning phases and key considerations for any MEC project. These worksheets provide guidance on the seven-step DQO process and other planning considerations; however, they do not cover new technologies. The template may be downloaded from http://www.ert2.org/T2MRPortal/pages/mrqa.html.

9.2. Geophysical Planning Strategies for Remedial or Removal Actions.

9.2.1. Introduction.

9.2.1.1. Planning geophysical investigations for MR actions requires an investigation strategy be developed to efficiently and effectively meet project needs. Developing the investigation strategy is a collaborative effort of all PDT members. The strategy defines which geophysical system or combinations of systems are needed to meet project needs and objectives and how the systems are intended to be used to meet those needs and objectives. Geophysics used for response actions is very similar to that used for characterization, but the critical goals and needs are specific to detecting and removing UXO and DMM and project decisions are focused on clearly demonstrating those goals and needs have been met.

9.2.1.2. While RAs and removal actions may be performed using either analog or DGM methods, studies have shown that analog geophysical methods underperform DGM methods on standardized test sites and have a greater number of false alarms (SERDP/ESTCP/ITRC, 2006). If the PDT decides to use analog methods, there is a greater likelihood that UXO and DMM will be left behind at a higher rate than DGM methods. A key advantage of DGM methods over analog geophysical methods is that DGM can show 100% performance, which can't be shown for analog methods. A DGM system performing at 100% means that, through a rigorous QC program (including instrument functionality checks and blind seeding in production areas), the PDT can show that the digital geophysical system operated as intended and detected all munitions within the anomaly selection criteria. Because analog methods can't show 100% performance, there is a greater likelihood that UXO is left behind on an MRS after an analog RA than there is with an RA that uses DGM methods.

9.2.1.3. The likelihood that a dig team has positively resolved (i.e., removed the metallic source of an anomaly) for all the detected anomalies using traditional mag-and-flag or DGM/intrusive methods isn't 100% (i.e., dig teams don't typically clear all holes). If a PDT uses the classification process to determine anomalies that don't require excavation, there is also a possibility that one to several UXO are left undug due to misclassification. However, there are at least a couple reasons why the classification process failure rate is less than with the more traditional mag-and-dig or DGM process. First, the classification process provides the dig team with a better dataset, which includes the likely item type and depth at which the item is located, that the dig team can use as a guide to determine when the anomaly source has been positively resolved. Second, the classification dig list requires a smaller number of targets be investigated and the dig team is only digging TOIs; therefore, the UXO team does not become fatigued from digging significant quantities of non-TOIs. Although one or a few UXO may be left behind due to misclassification, this can be minimized through a rigorous QC process. In addition, it should be noted that MRSs typically have very few UXO relative to the total number of anomalies, and the classification process removes the TOIs where there is more likely to be interaction with receptors.

9.2.2. Specify Response Goals and Needs to be Addressed by Geophysical Investigations. Key elements of the response objectives must be specified before undertaking geophysical planning because significant cost savings can be achieved by tailoring the geophysical investigation plan to the response needs. The following are the most critical issues that affect geophysical investigation planning for RAs or removal actions.

9.2.2.1. Considerations for Both DGM and Analog Systems.

9.2.2.1.1. Based on the Decision Document or Record of Decision, what are the project-specific TOI present and depths they must be recovered to? List all items and their expected detection depths (see Section 6.6.2.4 on using response curves for detection capabilities).

9.2.2.1.2. Of the geophysical systems capable of detecting project-specific TOI, what is the effectiveness of each, and how easy or difficult is it to prove or demonstrate that effectiveness?

9.2.2.1.3. Will high-precision position reporting suffice for project needs or will geophysical data require high-accuracy position reporting as well?

- Measurement positions must be reported with high precisions. High accuracies are not required because reacquisition procedures are not affected by coordinate accuracy.

- Measurement positions must be reported with high accuracies to support the reacquisition procedures being used.

9.2.2.1.4. Will the project schedule support a multiphase field effort (e.g., DGM mapping followed by anomaly classification and intrusive investigation)?

- Yes, a multiphase approach is supported so that digging resources can be tailored to maximize efficiency.

- No, all work must be performed concurrently to minimize disruption to the community.

- No, all required work is clearly defined and planned, and no efficiencies will be gained through a phased approach.

9.2.2.1.5. Will reacquisition procedures be affected by the passage of time after data collection?

- No. Digging will occur soon after data collection, and reacquisition will be performed before temporary survey markers are lost or removed.

- No.  Digging will occur at some later time, and reacquisition procedures will not require recovery of survey markers used to collect geophysical data.

- Yes.  Digging will occur at some later time, and reacquisition procedures require recovery of low-order accuracy survey markers used to collect geophysical data.

9.2.2.1.6.   What are the vegetation conditions and are there constraints on vegetation removal (e.g., cost, habitat, endangered species)?

- Vegetation removal is constrained and/or costly.  Some response objectives may not be met due to these constraints.

- Vegetation removal is constrained and/or costly.  All response objectives must be met regardless of vegetation constraints or costs.

- Vegetation removal is not constrained but is costly.  Some response objectives may not be met due to these constraints.

9.2.2.1.7.   What are the cultural and/or access constraints?

- Cultural and/or access constraints will impede production rates; some response objectives may not be met due to these constraints.

- Cultural and/or access constraints will impede production rates.  All response objectives must be met regardless of cultural and/or access constraints or costs.

9.2.2.2.   Considerations for Digital Geophysical Systems.

9.2.2.2.1.  Is the sensor that will be used for the remedial action well characterized?

- Yes.  The sensor response curves will be used to determine an anomaly selection threshold, and the GSV process, including the IVS and blind seeding within the production area, will be used throughout the remedial action to verify sensor performance.

- No, but sensor response curves can be calculated.  After sensor response curves for the instrument have been calculated, the GSV process will be used throughout the remedial action to verify sensor performance.

- No, and sensor response curves can’t be calculated to determine the anomaly response characteristics.  The geophysical instrument will be tested in a GPO to determine the site-specific detection capabilities of the instrument.  In addition, an IVS will be used to demonstrate instrument functionality on a daily basis, and the production area will be blind seeded to ensure sensor performance throughout the remedial action.

9.2.2.2.2.   For well-characterized sensors, will the anomaly selection criteria be based upon detecting all munitions to a specific depth or removing all detectable munitions?

- If all munitions must be removed to a specific depth, the anomaly selection criteria are based on the sensor response of the most conservative munition in its least favorable orientation.

- If all detectable munitions must be removed, then the anomaly selection criteria are based on the intersection of a multiple of the background RMS noise (typically five to seven times the RMS noise level) and the sensor response curve for the most conservative munition in its least favorable orientation.

9.2.2.2.3. How will anomaly classification be implemented?

- The classification process will be defined up front and then applied globally to the remainder of the project site.

- The classification process will be defined up front and then tested on small subsets of anomalies periodically throughout the project's duration.

9.2.2.2.4. If anomaly classification is being applied at the site, how critical is it that ISOs be treated as TOIs?

- If all ISOs must be removed from the site because they have similar shapes, sizes, and responses to standard munitions, then the ISOs should be considered TOIs and performance metrics established for the anomaly classifier should include the removal of all ISOs.

- If ISOs may be treated as clutter, the anomaly classifier does not need to be tailored to include all potential ISOs as TOIs. The classification process must still properly classify ISOs in order to show, as part of the QC process or classification verification process, that the classifier is functioning properly.

9.2.2.2.5. How critical is it to achieve a 90% confidence level that there is less than 1% unresolved anomalies remaining after intrusive investigation and post-dig anomaly resolution sampling?

- If a lesser confidence level and/or greater percent unresolved anomalies is acceptable, sample IAW Table 6-6 for the confidence level and percent unresolved anomalies values specified for the project.

- If this confidence level and percent unresolved anomalies are acceptable, perform post-dig anomaly resolution sampling IAW Table 6-6.

- If a greater confidence level is required, sample IAW Table 6-6 for the confidence levels and percent unresolved anomalies values specified for the project.

9.2.2.3. Considerations for Analog Geophysical Systems. How critical is it to achieve a 90% confidence level that there is less than 1% unresolved anomalies remaining after intrusive investigation and post-dig anomaly resolution sampling?

- If a lesser confidence level and/or greater percent unresolved anomalies is acceptable, sample IAW Table 6-6 for the confidence level and percent unresolved anomalies values specified for the project.

- If this confidence level and percent unresolved anomalies are acceptable, perform post-dig anomaly resolution sampling IAW Table 6-6.

- If a greater confidence level is required, sample IAW Table 6-6 for the confidence levels and percent unresolved anomalies values specified for the project. Specify the Removal Decision Exit Strategy.

9.2.3. Geophysical Decision Logic Strategies.

9.2.3.1. Strategies should be centered on exactly how much data are needed to support the decision that the removal is complete.

9.2.3.2. The PDT must decide what findings constitute delineating an area as complete. A combination of statistical tools, geophysical anomaly patterns, excavation results, and QC testing results should be factored into the decision logic. The decision logic should include all reasonable sources of evidence, and the PDT must determine which are basic, optimal, and excessive sources of evidence. The sources of information the PDT should use include, but are not limited to, the following:

a. Dig results for all anomalies selected for excavation

b. Distribution patterns of recovered TOIs from throughout the site

c. Detection depth capabilities for each TOI

d. Deepest depth from which each TOI type was recovered

e. Depth requirement

f. Numbers of non-TOI anomalies investigated and their dig results

g. Geophysical anomaly densities (e.g., anomalies per acre)

h. Visual observations

i. QC results

j. Findings from post-removal verification of anomaly locations and dig results

k. Findings from post-removal verification using mapping techniques

l. Previous work performed in the project area

9.2.4. Decision Diagrams.

9.2.4.1. Once all sources of information are defined, the PDT then must identify the assumptions for each source used, and this information must be conveyed to all team members. One tool for conveying this information is a decision diagram.

9.2.4.2. Figures 9-1 and 9-2, respectively, show example RA decision logic diagrams for DGM and analog removal actions. These diagrams present simplified decision logics that use geophysical anomaly characteristics, dig results, QC results, and QASP results to explain how decisions will be derived to declare areas cleared of detectable MEC hazards. See Chapter 6 for further details on anomaly detection, selection, and classification and Chapter 11 for further details on QA/QC and corrective action measures.

## Example DGM Removal Decision Logic

**Project Description**

1 Project area is 100 acres
2 Access unimpeded, close to 100% mapping is achievable.
3 Vegetation does not impede project needs/objectives.
4 Decision Document requires removal of all TOI hazards to 3' bgs. TOI types and their depths are well defined from previous site-specific work.
5 The project area is divided into 10 acre sub-sectors for purposes of product delivery and progress payments.

| List of MEC | Deepest Known (inches) | Deepest Estimated (inches) | Deepest Detectable Depth at Worst Orientation (inches) |
|---|---|---|---|
| 57mm | 12 | 12 | 25 |
| 75mm | 17 | 17 | 36 |
| 155mm | 27 | 27 | 50 |

**Assumptions**

1 Site is easy to access, brush clearing is allowed and unrestricted.
2 DGM will be used to detect all anomalies.
3 Concentrated metal contamination around target area will be removed prior to DGM.
4 Advanced EMI sensor will be used for anomaly classification of identified targets. Targets will be classified as likely TOI (Cat. 1), can't determine if target is TOI or clutter (Cat. 2), unknown (Cat. 3), or target likely clutter (Cat. 4).
5 All anomalies within Categories 1-3 will be intrusively investigated to confirm the anomaly classification. Additional types of TOI are not anticipated.
6 QC and QA will include verifying all anomalies having TOI characteristics are placed on dig lists and checking excavated locations for 90% or more reduction in signal. Post-dig verification sampling will be conducted in accordance with Table 6-5 of EM 200-1-15.
7 All performance metrics listed on Table 11-5 of EM 200-1-15 will be achieved.

| **Anomaly Characteristics Decision Logic** | | |
|---|---|---|
| **Anomaly Category** | **Anomaly Characteristic** | **Dig Decision** |
| Category 1 | Classification algorithm can analyze anomaly characteristics - target likely MEC. | Dig all anomalies |
| Category 2 | Classification algorithm can analyze, but can't determine whether target is MEC or clutter | Dig all anomalies |
| Category 3 | Classification algorithm can't analyze anomaly characteristics (e.g., low SNR, overlapping signals) | Dig all anomalies |
| Category 4 | Classification algorithm can analyze anomaly characteristics - target likely clutter. | Do not dig |

Figure 9-1: Example DGM Removal Decision Logic

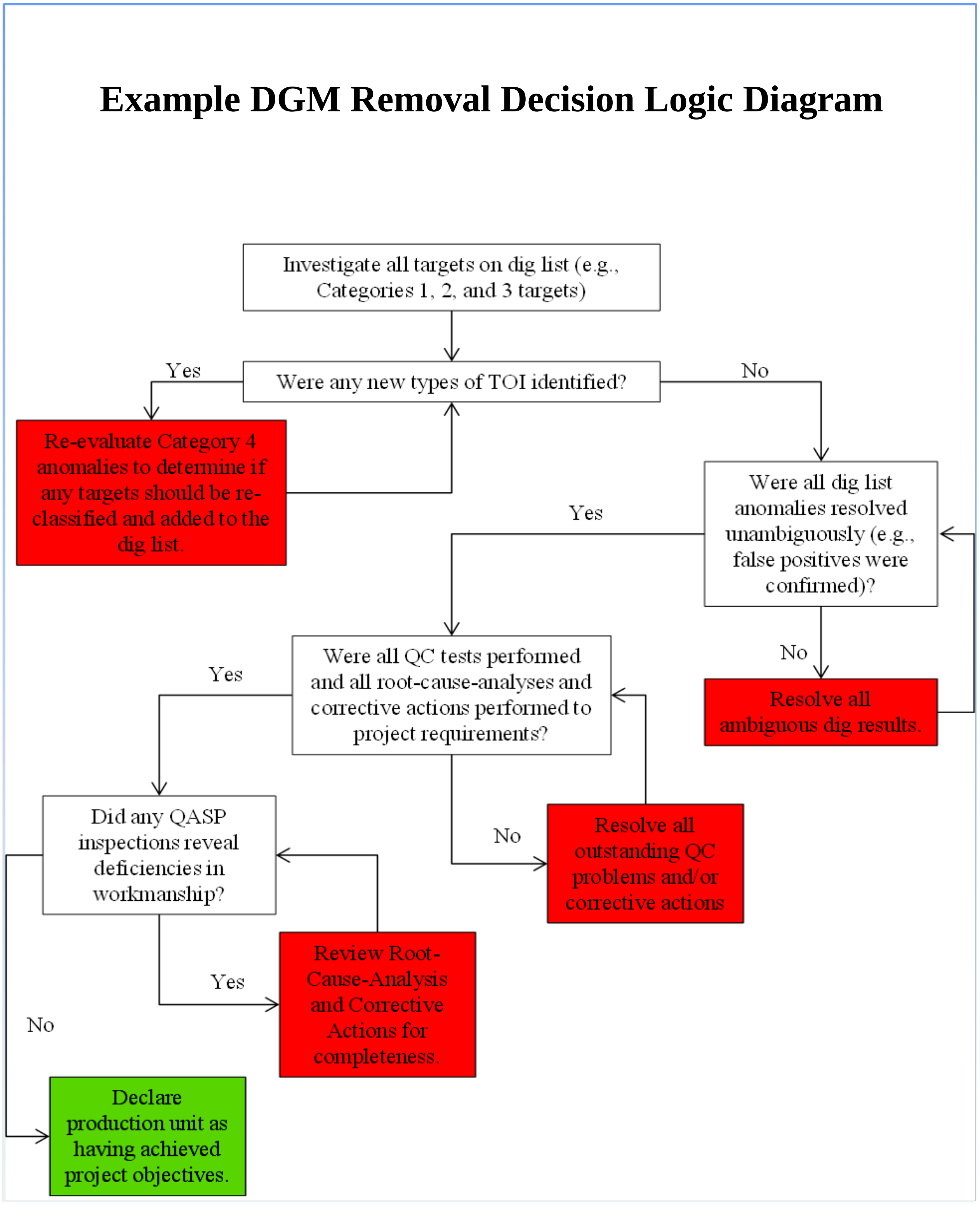



Figure 9-2  Example DGM Removal Decision Logic Diagram

## Example Analog Geophysical Removal Decision Logic

**Project Description**

1. Project area is 100 acres.
2. Access unimpeded, close to 100% mapping is achievable.
3. Vegetation does not impede project needs/objectives.
4. Decision Document requires removal of all MEC hazards to 3' bgs. TOI types and their depths are well defined from previous site-specific work.
5. The project area is divided into 10 acre sub-sectors for purpose of product delivery and progress payments.

**Assumptions**

1. Site is easy to access, brush clearing is allowed and unrestricted.
2. An analog mag and dig approach will be used to detect and remove all anomalies.
3. All detected anomalies will be excavated.
4. QC and QA will verify all detectable anomalies are flagged for excavation.
5. Post-dig verification sampling will be conducted in accordance with Table 6-5 of EM 200-1-15.
6. All RA performance metrics listed on Table 11-6 of EM 200-1-15 will be achieved

| List of MEC | Deepest Known (inches) | Deepest Estimated (inches) | Deepest Detectable Depth at Worst Orientation (inches) |
|---|---|---|---|
| 57mm | 12 | 12 | 20 |
| 75mm | 17 | 17 | 31 |
| 155mm | 27 | 27 | 42 |

Figure 9-3: Example Analog Geophysical Removal Decision Logic

9.3. Mass Excavation Planning Strategies for Remedial or Removal Actions.

9.3.1. Introduction.

9.3.1.1. Planning mass excavations for MR actions requires a strategy be developed to efficiently and effectively meet project needs. Developing the strategy is a collaborative effort of all PDT members. The strategy defines which excavation system or combinations of systems are needed to meet project needs and objectives and how the systems are intended to be used to meet those needs and objectives. Mass excavation is not likely to occur during other phases of an MMRP project (e.g., RI); therefore, the critical goals and needs are specific to removing UXO and DMM and project decisions are focused on clearly demonstrating those goals and needs have been met.

9.3.1.2. Maintaining site worker safety is a critical component of all MR actions but is especially important during mass excavation removal and remedial actions due to the use of heavy machinery to excavate UXO. The PDT should evaluate key factors, such as armoring excavators, using physical barriers between site workers and the active excavation, and using robotics to allow site workers to remain at a safe distance from excavation activities. Technical guidance on excavators is discussed in Section 9.1 and UXO safety procedures are discussed in EM 385-1-97.

## Example Analog Geophysical Removal Decision Logic Diagram

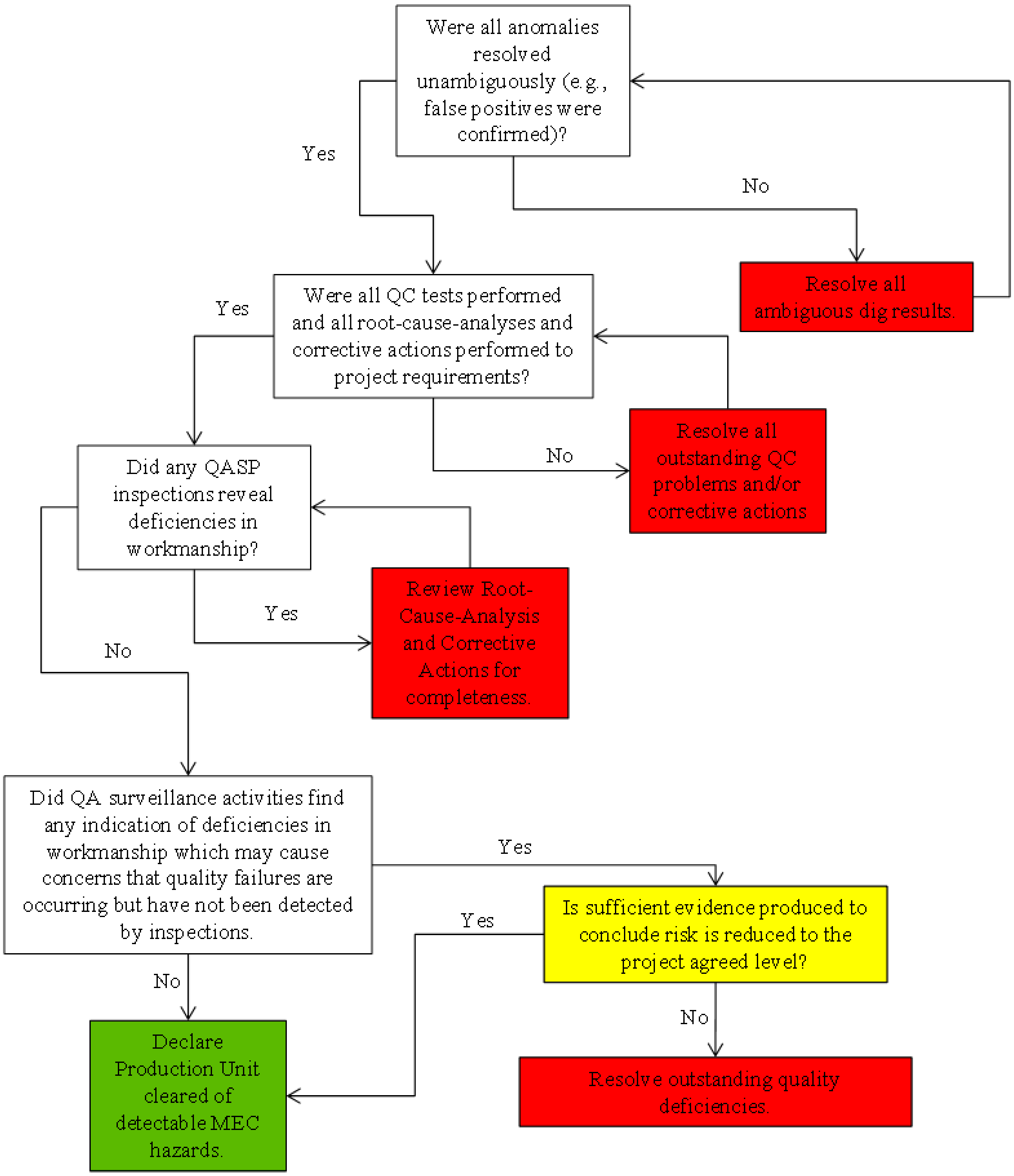


Figure 9-4: Example Analog Geophysical Removal Decision Logic Diagram

9.3.2. Specify Response Goals and Needs to be Addressed by Mass Excavation.

9.3.2.1. Key elements of the response objectives must be specified before undertaking mass excavation planning because significant cost savings can be achieved by tailoring the MR action plan to the response needs. The following are the most critical issues that affect mass excavation planning for RAs or removal actions.

9.3.2.1.1. Based on the Decision Document or Record of Decision, what are the project-specific UXO or DMM present and depths they must be recovered to? List all items and their expected penetration depths.

9.3.2.1.2. Of the mass excavation systems capable of removing and screening project-specific UXO, what is the effectiveness of each, and how easy or difficult is it to prove or demonstrate that effectiveness?

9.3.2.1.3. Will the project schedule support a multiphase field effort (e.g., excavation followed by sifting operations)?

- Yes, a multiphase approach is supported so that excavation resources can be tailored to maximize efficiency.

- No, all work must be performed concurrently to minimize disruption to the community.

- No, all required work is clearly defined and planned, and no efficiencies will be gained through a phased approach.

9.3.2.1.4. What are the vegetation conditions and are there constraints on vegetation removal (e.g., cost, habitat, endangered species)?

- Vegetation removal is constrained and/or costly. Some response objectives may not be met due to these constraints.

- Vegetation removal is constrained and/or costly. All response objectives must be met regardless of vegetation constraints or costs.

- Vegetation removal is not constrained but is costly. Some response objectives may not be met due to these constraints.

9.3.2.1.5. What are the cultural and/or access constraints?

- Cultural and/or access constraints will impede production rates; some response objectives may not be met due to these constraints.

- Cultural and/or access constraints will not impede production rates. All response objectives must be met regardless of cultural and/or access constraints or costs.

9.3.2.1.6. Are there areas within the MRS where the terrain is inaccessible to the excavation equipment?

- No. Excavation will occur across the entire MRS.

- Yes. DGM or analog geophysical investigations will be performed in the areas that are inaccessible to the excavators.

9.3.2.1.7. Will the soil type (e.g., clay) affect the ability of the screen to segregate clumps of soil from metallic debris?

- Yes. The type of soil will result in significant quantities of clumped soil, which will decrease the effectiveness of the sifting operation in segregating soil from metallic debris. Shakers and/or multiple screens will be used to minimize the effect on the effectiveness of the sifting operation.

- No. Soil type will not have a significant effect on the production rate of the sifting operations.

9.3.2.1.8. How will the completeness of the excavation be determined?

- If the MRS must be clear of all UXO or DMM, perform post-excavation DGM surveying and excavation to verify there are no geophysical anomalies below the excavation.

- If mass excavation is to a specific depth, verify that the required depth of excavation has been achieved.

9.3.2.1.9. How will the required excavation goals be verified in the field?

- If the project requires all UXO or DMM be removed from the site, perform post-excavation DGM verification surveying to confirm that there are no anomalies below the total depth of the excavation. If anomalies exist, either perform further mass excavation or have UXO technicians excavate anomalies using hand tools.

- If the project requires the excavation be performed to a specific depth, topographic surveying of the ground surface prior to excavation and after the excavation has reached the targeted depth will verify that the total depth has been met. Post-excavation DGM verification surveying also may be conducted to determine where anomalies exist below the required excavation depth.

9.3.3. <u>Strategies Should Be Centered on Exactly How Much Data Are Needed to Support the Decision that the Removal Is Complete</u>.

9.3.3.1. The PDT must decide what findings will constitute delineating an area as complete. A combination of the amount of excavated soils, process descriptions, excavation results, and QC testing results should be factored into the decision logic. The decision logic should include all reasonable sources of evidence, and the PDT must determine which are basic, optimal, and excessive sources of evidence. The sources of information the PDT should use include, but are not limited to, the following:

a. Excavation results for all areas selected for excavation

b. Distribution patterns of recovered TOI from throughout the site

c. Deepest depth from which each TOI type was recovered

d. Depth requirement

e. Amount of recovered non-TOI identified during the excavation

f. Distribution of TOI densities (e.g., TOI per acre)

g. Visual observations

h. QC results

i. Findings from post-removal verification DGM surveys (if performed)

j. Findings from excavation of anomalies identified in post-removal DGM verification surveys

k. Previous work performed in the project area

9.3.3.2. Once all sources of information are defined, the PDT then must identify the assumptions for each source used, and this information must be conveyed to all team members. One tool for conveying this information is a decision diagram. Figure 9-3 shows an example RA decision logic diagrams for mass excavation removal actions. This diagram presents simplified decision logics that use mass excavation and QASP results to explain how decisions will be derived to declare areas cleared of MEC hazards.

# Example Mass Excavation Removal Decision Logic

**Project Description**
1 Project area is 100 acres
2 Access unimpeded, close to 100% excavation is achievable.
3 Vegetation does not impede project needs/objectives.
4 Decision Document requires removal of all TOI hazards to 3' bgs. TOI types and their depths are well defined from previous site-specific work.
5 The project area is divided into 1 acre sub-sectors for purposes of product delivery and progress payments.

| List of MEC | Deepest Known (inches) | Deepest Estimated (inches) |
|---|---|---|
| 57mm | 12 | 12 |
| 75mm | 17 | 17 |
| 155mm | 27 | 27 |

**Assumptions**
1 Site is easy to access, brush clearing is allowed and unrestricted.
2 Detector assisted surface removals will occur prior to excavation.
3 An excavator will be used to remove soil in 1-ft lifts. Soil will be taken to a staging area to
4 Topographic surveys are conducted before and after the excavation to verify that the excavation has reached the target depth of 3 ft bgs.
5 QC and QA will verify all metallic fragments have been removed from the soil and that the target depth of 3 ft bgs has been reached.
6 Post-excavation DGM surveying will identify geophysical anomalies remaining in the ground, but will not be excavated if the target depth has been reached.

Figure 9-5: Example Mass Excavation Removal Decision Logic

# Example Mass Excavation Removal Decision Logic Diagram

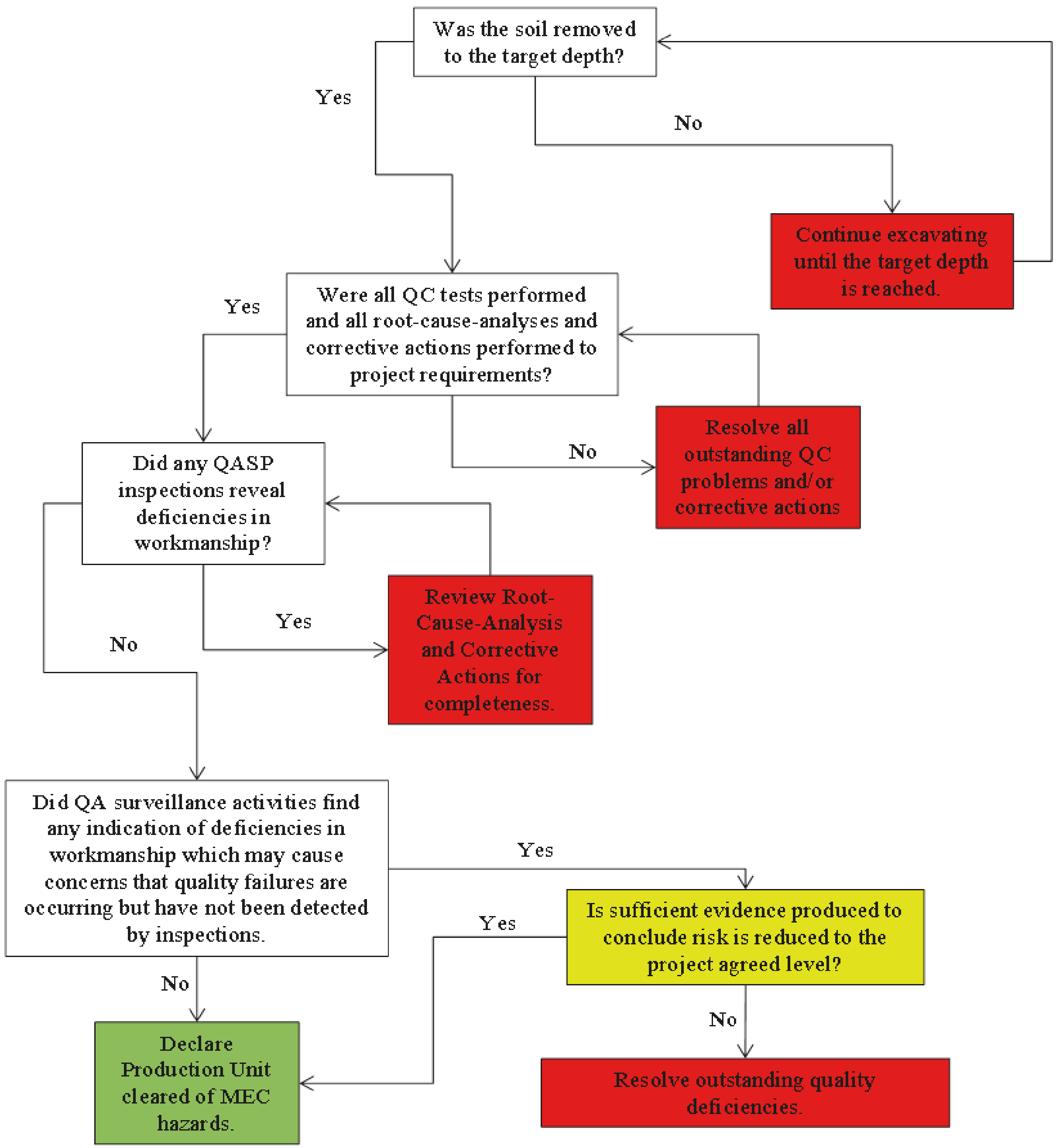



Figure 9-6 Example Mass Excavation Removal Decision Logic Diagram

# CHAPTER 10

## Munitions Constituents Planning Considerations for Remedial or Removal Actions

10.1. Introduction.

10.1.1. Planning considerations for MC RAs or removal actions at MRSs are dependent on the medium that is to be addressed (typically soil and/or groundwater), as well as the technologies employed for remediation or removal. The technologies used for MRS RAs or removal actions are very similar to those developed for use at HTRW sites.

10.1.2. This chapter provides an overview of the technologies applicable to soil and groundwater at various types of MRSs and discusses key considerations for the application of these technologies at MRSs. The PDT is encouraged to explore the following Web sites for guidance on applicability and implementation of various treatment technologies:

a. Federal Remediation Technologies Roundtable http://www.frtr.gov/matrix2/top_page.html

b. USEPA Hazardous Waste Cleanup Information http://www.clu-in.org/techfocus/

10.2. Regulatory Considerations.

10.2.1. MC can be subject to various environmental laws; thus, the regulatory status of MC must be considered during the planning process.

10.2.2. ARARs must be identified for removal and remedial actions because they affect the decision making process. For example, under RCRA, actions involving hazardous waste may require selection of treatment technologies capable of meeting land disposal restriction treatment standards; treatment residues constituting solid waste may be subject to solid waste disposal standards; and certain metals may qualify for an exclusion from RCRA if properly recycled.

10.3. Small Arms Range Cleanup.

10.3.1. MC encountered at SARs are primarily metals—lead, antimony, copper, zinc, and arsenic—that leach from bullets, bullet jackets, bullet fragments, and shotgun pellets. PAHs that leach from clay targets also may be present at skeet and trap ranges. At rifle and pistol ranges, most training is done with fixed or stationary targets positioned in front of a soil berm. This soil berm typically receives a heavy accumulation of lead and may fail standard leachability tests, such as the RCRA TCLP and the Synthetic Precipitation Leaching Procedure. Remediation of these ranges involves a relatively small volume of soil that is heavily contaminated. Shotgun ranges (i.e., skeet and trap ranges), on the other hand, typically have widely dispersed lead particles. Remediation of these ranges involves large soil volumes with relatively low particulate lead concentrations. Prior to conducting remediation at SARs, review of the following publications is recommended.

a. U.S. Army Environmental Command (USAEC) software/documentation for SARs, available through USAEC:

b. “REST” (Range Evaluation Software Tool)

c. “ASAP” (Army Sampling and Analysis Plan)

d. ITRC Guidance: Characterization and Remediation of Soils at Closed Small Arms Firing Ranges http://www.itrcweb.org/Documents/SMART-1.pdf

e. Treatment and Management of Closed or Inactive Small Arms Firing Ranges (ERDC / EL TR-07-06) http://el.erdc.usace.army.mil/elpubs/pdf/trel07-6.pdf

f. USEPA Region 2 Guidance: Best Management Practices for Lead at Outdoor Shooting Ranges http://www.epa.gov/region02/waste/leadshot/

g. USEPA Technical Review Workgroup (TRW) Recommendations for Performing Human Health Risk Analysis on Small Arms Shooting Ranges (OSWER #9285.7-37) http://www.epa.gov/superfund/programs/lead/products/firing.pdf

10.3.2. Considerations for selecting treatment options at SARs include volume of impacted media, characteristics of the impacted media (e.g., contaminant concentrations, soil type, and depth of contaminated media), costs, length of time allowed for remediation, and post-treatment site use considerations. Figure 10-1 shows a sample treatment train decision tree for SARs. The technologies listed on the decision tree are described below

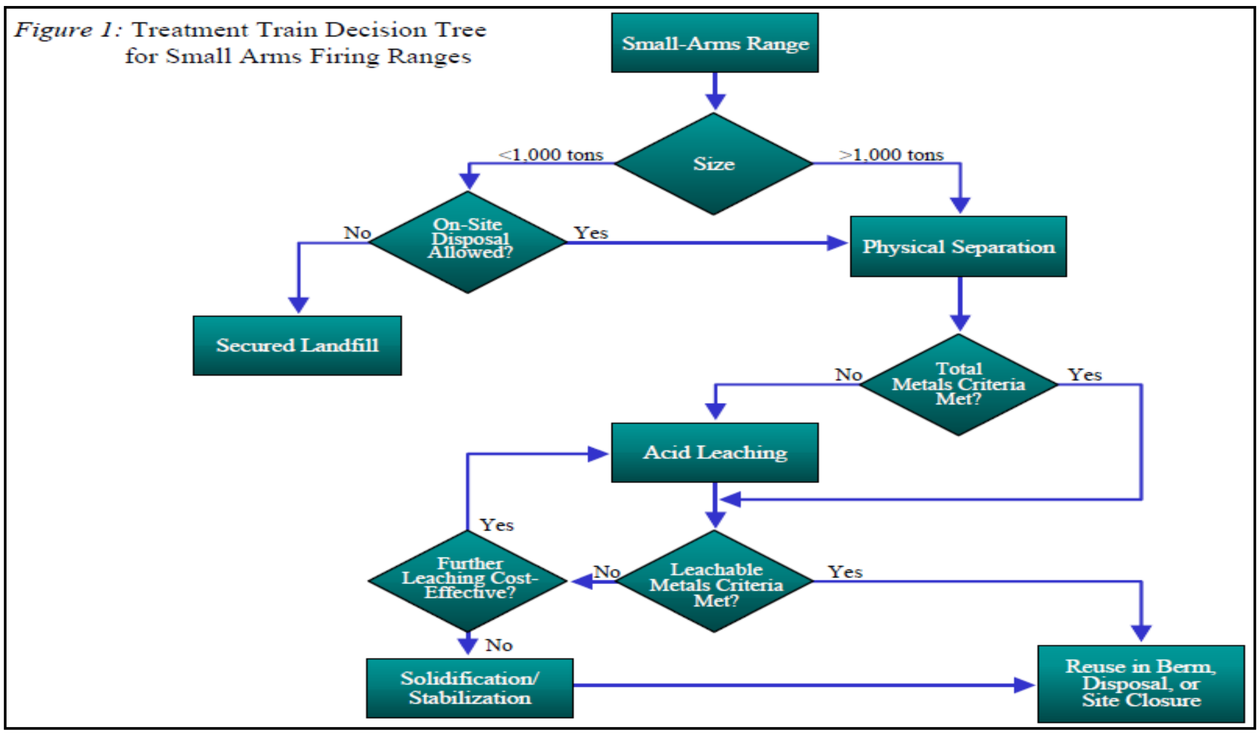



Figure 10-1: SAR Treatment Train Decision Tree

Source: Michael Warminsky, “Adapting Remedial Technologies to Meet Site-Specific Risk-Based Cleanup Goals, A Case Study of the MCA/GCC 29 Palms Range Soil Remediation Project,” from Appendix A of Characterization and Remediation of Soils at Closed Small Arms Firing Ranges, Technical/Regulatory Guidelines, ITRC 2003 Characterization and Remediation of Soils at Closed Small Arms Firing Ranges, available at http://www.itrcweb.org/Documents/SMART-1.pdf.

10.3.3. In addition to characterizing the nature and extent of MC and PAH contamination, the following parameters commonly are recommended to support the selection and design of soil treatment at SARs:

a. Grain-size distribution of soil

b. Clay content

c. Organic content

d. Soil pH

e. Contaminant form

f. Contaminant distribution versus grain-size

10.3.4. Currently available soil treatment technologies are discussed in the following sections.

10.3.4.1. Soil Screening. Soil screening may be performed to remove bullets, lead slugs, and metal fragments, particularly from berm soil. The screening process involves an initial screening to remove large debris, and then a second, smaller screen is used to remove lead fragments. Screening does not remove the lead attached to fine soil particles and also may not reduce the lead levels below TCLP criteria. Once the lead fragments have been removed, they may be sent to a smelter for recycling. Under 40 CFR 261.6(a)(3)(ii) and 40 CFR 261.4(a)(13), recycled lead is not subject to the requirements for generators, transporters, and storage facilities of hazardous wastes. Therefore, the scrap metal reclaimed from a SAR does not need to be regulated or manifested as a hazardous waste during generation or transport to a smelter for recycling. However, transport of this material may require a bill of lading IAW Title 49 CFR Subchapter C DOT hazardous materials regulations. Screened soil may qualify for reuse on site with the SAR; however, restrictions may apply to soil regulated as hazardous waste (i.e., soil that exceeds TCLP criteria).

10.3.4.2. Excavation and Disposal. Excavation and disposal (also termed (dig and haul") may be a cost effective approach for small volumes of soil. Before this approach is selected, the PDT must confirm whether the soil would be classified as a RCRA hazardous by testing appropriate constituents using the TCLP method and applying the contained-in rule. The soil would be classified as a RCRA hazardous if the TCLP result exceeds 5.0 milligrams per liter (mg/L) for lead or 5.0 mg/L for arsenic or fails TCLP for any other constituents listed in 40 CFR 261.24 and must be managed as a hazardous waste. It the soil contains leas or other constituents below the TCLP levels, it may still be regulated as a hazardous substance and must be disposed of IAW federal and state regulations. The PDT should consider technologies to reduce the volume of soil requiring off-site disposal (e.g., soil screening and soil washing).

10.3.4.3. Soil Washing. Soil washing is primarily a particle separation process. Soil washing classifies soil fractions by both size and density. Particle size separation is performed via sequential screening steps. Wet screening generally is more effective than dry screening; however, for sandy soil, dry processing may be feasible and typically offers cost savings over wet screening. Sand screws and/or hydrocyclones are used to classify the soil through segregation of the contaminant-bearing fractions (i.e., fine fractions) from the cleaner sand and gravel fractions. Gravity separation then is used to remove heavy, metal particles from same-size but lighter sand/gravel particles. After soil washing or dry screening to remove bullet fragments, follow-on treatment (e.g., soil stabilization) may be necessary to achieve acceptable metals levels to allow the soil to be shipped to a nonhazardous waste landfill. The particulate lead that is separated from the soil may be sent to a smelter for recycling, as described in Section 10.3.4.1. Soil washing is most effective for sandy soil and is more difficult for soil with high silt and/or clay content. It may be performed in a relatively short timeframe. Costs for soil washing range from $30/ton to $80/ton. Guidance for implementing soil washing may be found in these publications:

- Final Implementation Guidance Handbook: Physical Separation and Acid Leaching to Process Small-Arms Range Soils. 1997. NTIS: ADA341141. https://portal.navfac.navy.mil/portal/page/portal/navfac/navfac_ww_pp/navfac_nfesc_pp/environmental/erb/resourceerb/rpt-sar-imple.pdf

- Innovative Site Remediation Technologies: Design and Application, Vol. 3: Liquid Extraction Technologies Soil Washing, Soil Flushing, Solvent/Chemical. 1998. M.J. Mann, et al. American Academy of Environmental Engineers, Annapolis, MD. ISBN: 1-883767-19-9. http://clu-in.org/download/contaminantfocus/dnapl/treatment_technologies/soil-washing-soil-flushing.pdf

- Soil Washing Through Separation/Solubilization: Guide Specification for Construction. 2010. USACE. CEGS-02 54 23. http://www.wbdg.org/ccb/DOD/UFGS/UFGS%2002%2054%2023.pdf

- Technical and Regulatory Guidelines for Soil Washing. 1997. ITRC Metals in Soils Team. http://www.itrcweb.org/Documents/MIS-1.pdf

10.3.4.4. Solidification/Stabilization. The goal of solidification and stabilization techniques is to reduce the leachability of metals in soil so that the soil will not be classified as a RCRA hazardous waste. Solidification refers to a process that binds a contaminated media with a reagent, changing its physical properties. Stabilization refers to the process that involves a chemical reaction that reduces the leachability of contaminants within a material. Solidification/stabilization treatment typically involves mixing a binding agent into the contaminated media. This may be done in situ, by injecting the binder agent into the contaminated media, or ex situ, by excavating the contaminated media and machine mixing them with the agent. Ex situ mixing, typically using pug mills, allows for more uniform mixing and better contact between amendment and contaminant. Common types of solidifying/stabilizing agents include Portland cement, gypsum, modified sulfur cement, and grout. A bench-scale study typically is performed to determine a dosage rate and reagent mixture that meets the project performance standards. Post-treatment performance verification, typically including TCLP testing, is required at a frequency that optimally should match the daily operation throughput of the selected technology. Costs for solidification/stabilization range from $125/cubic yard (cy) to $185/cy for small-scale systems (less than 1000 cy) and from $70/cy to $145/cy for larger-scale systems (approximately 50,000 cy) (USEPA, 2009). Guidance for implementing solidification/stabilization may be found in these publications:

- Technology Performance Review: Selecting and Using Solidification/Stabilization Treatment for Site Remediation. 2009. USEPA 600-R-09-148 http://www.epa.gov/nrmrl/pubs/600r09148.html

- Solidification/Stabilization Resource Guide. 1999. USEPA 542-B-99-002 http://www.clu-in.org/download/remed/solidstab.pdf

- Recent Developments for In Situ Treatment of Metal Contaminated Soils. 1997. USEPA 5420R-97-004. http://www.clu-in.org/download/remed/metals2.pdf

10.3.4.5. Chemical Extraction. Chemical extraction involves the use of an acid solution to leach lead from contaminated soil after the bullets and bullet fragments have been removed via screening. Hydrochloric acid is used most often for chemical leaching and has been shown to be more effective than acetic acid.

10.3.4.5.1. Chemical treatment is a continuous process with the following steps:

- Acid and soil are mixed together in a leach tank.

- The leached soil is separated from the spent leachant.

- The spent leachant is regenerated by precipitating the dissolved metals.

10.3.4.5.2. Chemical extraction may be combined with soil washing. Treated soil may be disposed of on site if applicable ARARs are met. The metals recovered from the leachant solution may be recovered by a recycling facility. Guidance for implementing chemical extraction may be found in the following publication: Final Implementation Guidance Handbook: Physical Separation and Acid Leaching to Process Small-Arms Range Soils. 1997. NTIS: ADA341141 (https://portal.navfac.navy.mil/portal/page/portal/navfac/navfac_ww_pp/navfac_nfesc_pp/environmental/erb/resourceerb/rpt-sar-imple.pdf).

10.4. Energetics and Perchlorate Treatment Considerations.

10.4.1. Soil Treatment. A variety of technologies is available to treat energetic compounds and perchlorate in soil. The selection of an appropriate technology is guided by the RAOs for soil and by the MRS characteristics. The discussion below focuses on technologies that have been used at full-scale sites to treat energetics and/or perchlorate.

10.4.1.1. In Situ Biological Treatment. In situ biological treatment technologies include gaseous amendment injection for vadose zone bioremediation and phytoremediation.

10.4.1.1.1. Gaseous amendment injection involves the addition of a gas mixture to the vadose zone soil to displace oxygen and to produce conditions suitable for anaerobic bacteria to treat the target contaminant(s). Gas mixtures may include nitrogen, hydrogen, and hydrocarbon-containing gas (e.g., propane, natural gas). Gaseous amendment injection is not feasible for surface soils unless there is an impermeable cover to prevent atmospheric oxygen from seeping into the treatment area. Gaseous amendment injection has been demonstrated for perchlorate treatment under an ESTCP grant (Evans, 2010). This technology also has been demonstrated for RDX treatment at the DOE's Pantex facility (Rainwater et al., 2002). Information regarding these studies may be found in the following references:

- Evans, P.J. 2010. In Situ Bioremediation of Perchlorate and Nitrate in Vadose Zone Soil Using Gaseous Electron Donor Injection Technology (GEDIT). ESTCP Project ER-0511, Final Report. http://clu-in.org/download/contaminantfocus/perchlorate/ER-0511-FR-1.pdf.

- Rainwater, K., C. Heintz, T. Mollhagen, and L. Hansen. 2002. In Situ Biodegradation of High Explosives in Soils: Field Demonstration. Bioremediation Journal 6(4):351-371. http://www.clu-in.org/download/remed/solidstab.pdf

10.4.1.1.2. Phytoremediation uses plants to remediate various media impacted with different types of contaminants. While phytoremediation typically is applied in situ, hydroponics allows for ex-situ application. Phytoremediation may occur via a number of plant processes, termed phytotechnologies. These phytotechnologies include the following mechanisms:

- Phytosequestration – The ability of the plant to sequester certain contaminants in the rhizosphere through exudation of phytochemicals and on the root through transport proteins and cellular processes.

- Rhizodegradation – The ability of the plant to exude phytochemicals, which enhance microbial biodegradation of contaminants in the rhizosphere

- Phytohydraulics – The ability of plants to capture and evaporate water off the plant and take up and transpire water through the plant.

- Phytoextraction – The ability of plants to take up contaminants into the plant with the transpiration stream.

- Phytodegradation – The ability of plants to take up and break down contaminants in the transpiration stream through internal enzymatic activity and photosynthetic. oxidation/reduction

- Phytovolatilization – The ability of plants to take up, translocate, and subsequently transpire volatile contaminants in the transpiration stream.

10.4.1.1.3. Phytotechnologies may be applied to explosive compounds as well as to heavy metals. Phytotechnologies potentially can treat soils, sludge, sediments, groundwater, and surface water. Energetics may be treated via various phytotechnologies. For instance, nitroreductases are produced in some plants that can reduce and breakdown TNT, RDX, and HMX. Although phytoremediation currently is being studied and applied to prevent migration of contaminants from areas with low levels of surface contamination, a potential future use is to prevent migration of contaminants from active training ranges. Genetically engineered plants are being developed for use on training ranges. Additional information pertaining to the use of phytoremediation at training ranges is available from these references:

- Phytoremediation: Transformation and Control of Contaminants. 2003. S.C. McCutcheon and J.L. Schnoor. J. Wiley, New York. ISBN: 9780471273042, 987 pp.

- Phytotechnology Technical and Regulatory Guidance and Decision Trees, Revised. ITRC Phytotechnologies Team. PHYTO-3, 187 pp. 2009. http://www.itrcweb.org/Documents/PHYTO-3.pdf.

- Identification of Metabolic Routes and Catabolic Enzymes Involved in Phytoremediation of the Nitro-Substituted Explosives TNT, RDX, and HMX. 2006. SERDP Project CU 1317, Final Technical Report. http://www.serdp.org/Program-Areas/Environmental-Restoration/Contaminants-on-Ranges/Protecting-Groundwater-Resources/ER-1317/ER-1317

- A periodically updated database of plant species organized by contaminant can be accessed on the ITRC Web site: www.itrcweb.org/teampublic_Phytotechnologies.asp.

10.4.1.2. Ex Situ Biological Treatment. Ex situ biological treatment technologies for soil include composting and landfarming.

10.4.1.2.1. Composting. Composting is a controlled biological process by which organic contaminants (e.g., TNT, RDX, HMX) are converted by microorganisms to innocuous, stabilized byproducts. Typically, thermophilic conditions (54 to 65 degrees Celsius) must be maintained to properly compost soil contaminated with energetics. The increased temperatures result from heat produced by microorganisms during the degradation of the organic material in the waste. In most cases, this is achieved by the use of indigenous microorganisms. Soils are excavated and mixed with bulking agents and organic amendments, such as wood chips, animal, and vegetative wastes, to enhance the porosity of the mixture to be decomposed. The mixture typically results in approximately 30% soil and 70% amendments. Maximum degradation efficiency is achieved through maintaining oxygenation (e.g., daily windrow turning), irrigation as necessary, and closely monitoring moisture content and temperature. There are three process designs used in composting: aerated static pile composting (compost is formed into piles and aerated with blowers or vacuum pumps), mechanically agitated in-vessel composting (compost is placed in a reactor vessel where it is mixed and aerated), and windrow composting (compost is placed in long piles known as windrows and periodically mixed with mobile equipment). Windrow composting is the least expensive design since it requires only a simple liner or asphalt pad and no aeration manifold. The cost for composting is approximately $300/ton. If a temporary building is required, then the costs may increase. Typical treatment times range from 2 to 4 weeks to reach cleanup goals, followed by a curing period. The following references provide guidance for composting of energetics-contaminated soil:

- Soil Composting for Explosives Remediation: Case Studies and Lessons Learned. U.S. Army Corps of Engineers Public Works Technical Bulletin 200-1-95. 17 May 2011. http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_95.pdf.

- Bioremediation of Soil Using Windrow Composting: Guide Specification for Construction. 2010. USACE. CEGS-02 54 21. http://www.wbdg.org/ccb/DOD/UFGS/UFGS%2002%2054%2021.pdf.

- Composting of Soils Contaminated by Explosives. 1997. EPA530-F-97-045. http://www.epa.gov/osw/conserve/rrr/composting/pubs/explos.pdf

10.4.1.2.2. Landfarming. Landfarming, also known as land treatment or land application, is an ex situ remediation technology for soils that reduces contaminant concentrations through biodegradation. Contaminants that are amenable to treatment via landfarming include petroleum products and PAHs. This technology usually involves spreading excavated contaminated soils in a thin layer on the ground surface and stimulating aerobic microbial activity within the soils through aeration and/or the addition of minerals, nutrients, and moisture. The enhanced microbial activity results in degradation of adsorbed contaminants through microbial respiration. If contaminated soils are shallow (i.e., less than 3 feet bgs), it may be possible to effectively stimulate microbial activity without excavating the soils. If contaminated soil is deeper than 5 feet, the soils should be excavated and reapplied on the ground surface. Typical times to reach cleanup goals are two to three seasons (climate and contaminant dependent). The cost typically ranges from $50 to $70 per cubic foot.

- Bioremediation of Soil Using Landfarming Systems: Guide Specification for Construction. 2010. USACE. CEGS-02 54 20. http://www.wbdg.org/ccb/DOD/UFGS/UFGS%2002%2054%2020.pdf.

- Bioremediation Using the Land Treatment Concept. 1993. EPA600-R-93-164 http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=30002Y6E.txt.

10.4.1.3. Alkaline Hydrolysis. Alkaline hydrolysis has been studied extensively for the degradation of secondary explosives (primarily TNT and RDX) in aqueous and soil systems. Laboratory studies have determined that the end products of alkaline hydrolysis are mostly small compounds that are readily biodegradable in natural systems. Alkaline hydrolysis may be used to prevent migration of contaminants from active training ranges and for bulk soil treatment. Ex situ treatment may be performed using a pug mill to mix hydrated lime or sodium hydroxide into soil to obtain a target pH of 12. Alternatively, lime or sodium hydroxide may be diced into soil for treatment. At a pH of 12, TNT and RDX are destroyed very rapidly. Soil may require post-treatment neutralization based on future uses. The amount of lime required for treatment depends on the soil's buffering capacity. The cost for alkaline hydrolysis treatment is typically less than $2000/acre/year.

- Jared L. Johnson, Deborah R. Felt, W. Andy Martin, Ronnie Britto, Catherine C. Nestler, and Steven L. Larson. 2011. Management of Munitions Constituents in Soil Using Alkaline Hydrolysis: A Guide for Practitioners. ERDC/EL TR-11-16 http://el.erdc.usace.army.mil/elpubs/pdf/trel11-16.pdf.

- Jeffrey L. Davis, Catherine C. Nestler, Deborah R. Felt, and Steven L. Larson. 2007. Effect of Treatment pH on the End Products of the Alkaline Hydrolysis of TNT and RDX. ERDC/EL TR-07-4 http://el.erdc.usace.army.mil/elpubs/pdf/trel07-4.pdf.

- Lance D. Hansen, Steven L. Larson, Jeffrey L. Davis, John M. Cullinane, Catherine C. Nestler, and Deborah R. Felt. 2003. Lime Treatment of 2,4,6-Trinitrotoluene Contaminated Soils: Proof of Concept Study. ERDC/EL TR-03-15. http://el.erdc.usace.army.mil/elpubs/pdf/trel03-15.pdf.

10.4.1.4. Leaching from Vadose Zone Soils. This technology entails flushing the vadose zone with water introduced via an infiltration gallery to leach MC from the soil. The leachate is then recovered using a network of wells and treated (see ex situ groundwater treatment options below) and disposed of or recycled for use in the leaching treatment. This technology is only applicable to mobile MC, such as perchlorate and RDX. This option may be feasible when perchlorate is present in a relatively thick vadose zone (e.g., southwestern United States) and there are few other viable options. However, there are several limitations associated with this option:

- Uniform distribution of infiltration water becomes more difficult as the depth from the infiltration application point increases.

- Extracted water needs ex situ treatment before it can be reused for infiltration.

- The groundwater capture system needs to be very robust to prevent migration of contaminants from the treatment area.

10.4.1.4.1. A potential enhancement of this technology would be to amend the flush water with electron donor and/or nutrients to foster biodegradation of perchlorate (see Section 10.4.2.1.1). Vadose zone flushing has been implemented at Edwards Air Force Base (Battey et al, 2007).

10.4.2. Groundwater Treatment. A variety of groundwater treatment technologies are available to remediate energetic and perchlorate in groundwater. Treatment technologies may be applied in situ, or the groundwater may be extracted and then treated.

10.4.2.1. In Situ Treatment.

10.4.2.1.1. Enhanced In Situ Anaerobic Bioremediation. Enhanced in situ anaerobic bioremediation involves the delivery of an organic substrate into the subsurface for the purpose of stimulating microbial growth and development, creating an anaerobic groundwater treatment zone, and generating hydrogen through fermentation reactions. This creates conditions conducive to anaerobic biodegradation of perchlorate and certain energetics dissolved in groundwater. In situ anaerobic bioremediation of other contaminants, such as chlorinated solvents, is well documented in the literature, and much of the information regarding types of organic substrates and substrate delivery applies to energetics and perchlorate remediation (see AFCEE, 2004). Organic substrates that are commonly used include lactic acid, molasses, corn syrup, and emulsified oil. Substrates may be injected using direct push points or permanent injection wells. Passive delivery relies on natural groundwater flow to distribute the organic substrate after the initial injection. Recirculation systems may be used to actively distribute the organic substrate throughout the treatment area using optimally located injection and extraction wells. A monitoring well network typically is established to assess the effectiveness of the bioremediation treatment. Parameters that are monitored include MC concentrations, concentrations of bioremediation daughter products (if applicable), depletion of electron acceptors (dissolved oxygen, nitrate, perchlorate, sulfate), and other water quality parameters (pH, dissolved oxygen, oxidation/reduction potential).

10.4.2.1.1.1. Perchlorate-reducing bacteria are nonfermenting microorganisms that use either chlorate or perchlorate as a terminal electron acceptor and a variety of different organic substrates (e.g., acetate, propionate, lactate) as electron donors (energy sources). Laboratory microcosm studies have shown that perchlorate-reducing bacteria are indigenous to many soils, sediments, surface waters, and groundwater. Moreover, these organisms often can be stimulated to degrade perchlorate to below detection by adding a microbial growth substrate (ITRC, 2008). At the most promising sites for perchlorate reduction, geochemical conditions appropriate for perchlorate-reducing bacteria and evidence of anaerobic biological reduction are already observed. Favorable geochemical conditions include a pH between 6.5 and 7.5, oxidation/reduction potential between 0 and 100 mV, low dissolved oxygen concentrations, and low nitrate levels.

10.4.2.1.1.2. Although biodegradation of TNT occurs under a wide range of environmental conditions, the rate is fairly slow. The transformation products 4-Am-DNT and 2-Am-DNT often are observed in TNT-contaminated groundwater. Under strongly reducing conditions (i.e., conditions created with addition of a carbon substrate), these products are believed to become irreversibly bound to organics and to the aquifer matrix. RDX is more readily degraded than TNT, especially under anaerobic conditions. Final products may include methanol and hydrazines, and under methanogenic conditions, methane. RDX generally requires more highly anaerobic conditions than perchlorate to stimulate biodegradation.

10.4.2.1.1.3. The following publications should be reviewed if enhanced in situ anaerobic bioremediation of perchlorate and/or energetics is being considered as a remedy at an MRS:

- Air Force Center for Environmental Excellence, Naval Facilities Engineering Service Center, and ESTCP. 2004. Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents. http://www.afcee.af.mil/shared/media/document/AFD-071130-020.pdf.

- Remediation Technologies for Perchlorate Contamination in Water and Soil. 2008. http://www.itrcweb.org/Documents/PERC-2.pdf.

- Altaf H. Wani, Deborah R. Felt, and Jeffrey L. Davis. Biologically Active Zone Enhancement (BAZE) Supplemental Study: Mass Balance of RDX Biotransformation and Influence of Aquifer Temperature on RDX Biodegradation in Groundwater. 2003. ERDC/EL TR-03-11. http://el.erdc.usace.army.mil/elpubs/pdf/trel03-11.pdf.

- Denise K. MacMillan and David E. Splichal. 2005. A Review of Field Technologies for Long-Term Monitoring of Ordnance-Related Compounds in Groundwater. ERDC/EL TR-05-14. http://www.clu-in.org/download/char/trel05-14.pdf.

- James M. Brannon and Judith C. Pennington. 2002. Environmental Fate and Transport Process Descriptors for Explosives. ERDC/EL TR-02-10. http://el.erdc.usace.army.mil/elpubs/pdf/trel02-10.pdf.

10.4.2.1.2. Phytoremediation. Phytoremediation for soil treatment is described in Section 10.4.1.1.2. The primary phytotechnology applicable to groundwater is phytohydraulics. The most significant limitation for groundwater is that phytoremediation is applicable only to shallow groundwater. Groundwater depths within 15 feet of the surface generally are accessible by most deep-planted applications. In some cases, phytoremediation may be applicable where groundwater transitions to surface water (e.g., daylighting seeps).

10.4.2.2. Ex Situ Treatment.

10.4.2.2.1. Ex situ treatment may be required when the selected remedy involves groundwater extraction and when the groundwater requires on-site treatment prior to discharge or reuse.

10.4.2.2.2. The following are references that provide comprehensive information on the most commonly used ex situ treatment technologies for groundwater:

- Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites. Directive 9283.1-12. USEPA 540/R-96/023. 1996. http://www.epa.gov/superfund/health/conmedia/gwdocs/gwguide/gwfinal.pdf.

- Remediation Technologies for Perchlorate Contamination in Water and Soil. 2008. http://www.itrcweb.org/Documents/PERC-2.pdf.

10.4.2.2.2.1. Granular Activated Carbon (GAC). A highly adsorbent material with very large surface-to-volume ratios, GAC commonly is used to remove contamination from water. Contaminated water is pumped through vessels filled with GAC. There are usually two vessels in series (i.e., lead-lag configuration), and sample ports typically are placed before and after each vessel to allow measurement of contaminant breakthrough. As water passes through the carbon, contaminants adsorb to the surface of the carbon particles. Most high molecular weight, organic contaminants (e.g., TNT, RDX) have a relatively strong affinity for GAC. RDX typically breaks through before TNT. The GAC medium is replaced when its adsorption capacity is reached. The spent GAC typically is returned to the GAC vendor for regeneration or destruction. Although standard GAC has not been found to efficiently remove perchlorate, the adsorptive capacity may be increased through coating the surface with a thin layer of a surface-active substance.

10.4.2.2.2.2. Ion Exchange. Ion exchange is a reversible chemical reaction caused when an ion from solution is exchanged with a similarly charged ion from an immobile solid. Contaminated water is pumped through vessels filled with ion exchange resin beads, and the targeted ions are removed from water through sorption onto solid resins. For instance, perchlorate ion may replace chloride on a resin. Perchlorate-selective ion exchange resins have been developed, and currently ion exchange is the most proven and widely accepted physical process technology to meet existing perchlorate treatment goals. The ion exchange resin is replaced when the exchange capacity is exhausted. Spent resin media are usually sent off site for regeneration or destruction.

10.4.2.2.2.3. Fluidized Bed Reactor. The fluidized bed reactor (FBR) is a reactor column that fosters the growth of microorganisms on a hydraulically fluidized bed of media, usually sand or activated carbon. The fluidized medium selected provides a large surface area on which a film of microorganisms can grow, thus producing a large inventory of biomass in a small reactor volume. The result is a system capable of high degradative performance for target contaminants in a relatively small and economical reactor volume. The FBR can be controlled to operate under aerobic, anaerobic, or anoxic conditions, depending upon the nature of the target compounds. For perchlorate and energetic, anaerobic conditions typically are targeted. FBRs are capable of achieving less than 4 μg/L of perchlorate in the effluent. RDX and TNT also have been successfully treated in FBRs. See the following publications for examples of FBR use for perchlorate and energetic:

- Fuller et al., Combined Treatment of Perchlorate and RDX in Ground Water Using a Fluidized Bed Reactor, Ground Water Monitoring & Remediation 27, no. 3. 2007. pages 59–64. http://info.ngwa.org/gwol/pdf/072082343.pdf.

- Stephen W. Maloney and Robert L. Heine. 2005. Demonstration of the Anaerobic Fluidized Bed Reactor for Pinkwater Treatment at McAlester Army Ammunition Plant. ERDC/CERL TR-05-8. http://el.erdc.usace.army.mil/elpubs/pdf/trel05-8.pdf.

# CHAPTER 11

# Quality Control

## 11.1. Introduction.

11.1.1. The general objective of MR actions is to efficiently locate buried UXO and DMM so it can be evaluated, recovered, and disposed of properly. The PDT must define project-specific objectives and performance metrics for each definable feature of work that will be measurable and attainable. The PDT also must define project-specific QC and QA processes for each definable feature of work to ensure that performance metrics are attained and project objectives are met.

11.1.2. On MR projects, there are two elements subject to QC/QA: processes and products. Processes are the project-specific planning and data collection / data analysis procedures and all related field activities performed. Products are the final project-specific deliverables and results that are achieved. QA primarily is a function of process oversight, while QC primarily is a function of checking measurable items (e.g., geophysical sensor velocity). QA and QC can be either government or contractor tasks. The PDT must define the products, which will vary depending on the type of task and project being performed. For example, the UXO RA product of having a cleared parcel of land is more important than it is for a characterization project, which may only require a parcel be characterized as having UXO impact or not. Possible deliverable products include complete project reports, geophysical data deliverables (e.g., properly formatted raw and processed geophysical data, legible geophysical maps, complete interpretations), intrusive investigation results (e.g., complete dig sheets with all relevant geophysical data and intrusive results), MC data deliverables (e.g., MC analytical laboratory results, data validation reports), GDS deliverables (e.g., MC sample locations, geophysical anomaly locations), and complete QC documentation IAW the UFP-QAPP.

11.1.3. When formulating the UFP-QAPP or QA activities, this chapter provides options that can be selected and tailored to the specific geophysical, MC, and GDS tasks that the PDT will perform. Details on required planning documents are provided in Chapter 4. The QC plans and tests that are designed as a function of the guidance in this chapter should be incorporated into the UFP-QAPP and may be reflected as elements of a project's QASP.

11.1.4. Although this chapter presents only QC considerations for MEC, MC, and GDS processes, additional QC guidance for these topics and others not covered within this chapter may be found in the ITRC Quality Considerations for Munitions Response Projects (2008) and the U.S. Navy's MEC UFP-QAPP template, which is available at: http://www.ert2.org/T2MRPortal/pages/MEC%20QAPP%20Template%20Sep%2009.doc. Guidance on the UFP-QAPP and the UFP-QAPP workbook format can also be found at http://www.epa.gov/fedfac/documents/qualityassurance.htm. Example topics not covered in this chapter include vegetation clearance, removal debris removal, and mass excavation.

## 11.2. Munitions and Explosives of Concern Quality Management.

11.2.1. General Munitions and Explosives of Concern Process Quality Management.

11.2.1.1. Sections 11.2.1 through 11.2.5 discuss MEC quality in the context of the geophysical system as defined in the introduction to Chapter 6. Because geophysical systems make use of DGM and/or analog geophysical mapping (also referred to as mag and flag or mag and dig operations), this section often will highlight whether a particular topic is relevant to DGM systems, analog systems, or both. When a topic is specific to systems using digital techniques, "digital" or "DGM" will be in parentheses after the topic; for systems using analog tools, "analog" will be in parentheses. Topics relevant to both types of systems will have the words "analog and digital" in parentheses. The reader is referred to Chapter 6 of this document for more details on digital and analog geophysical systems.

11.2.1.2. The project processes and the project products will be part of a formal quality management process in order to demonstrate that project objectives are met. In most instances where geophysical systems are used, whether digital or analog, emphasis will be placed upon process quality management because the success, or failure, of geophysical products is highly dependent upon how the systems are used. The intent of this section is to provide a guide for the PDT in identifying the important aspects of geophysical systems that will require monitoring for quality.

11.2.1.3. QC of the processes used to perform geophysical operations should focus on demonstrating data meet project needs and the data are used for their intended purpose. The PDT should explicitly define all data quality requirements. Statements such as "a clean site" or "a well characterized site" are ambiguous and cannot be used to develop rigorous QC or QA programs. Typically, the term "good data" is used to identify specific work products or specific definable features of work that are the result of specific work tasks or work functions. These tasks and functions can be viewed as key procedures in QC programs, and the individual components of the geophysical systems used in performing those procedures are referred to as subsystems. Breaking the work processes into key procedures and key subsystems helps the PDT identify how the work will be done as well as which tools will be used. Doing so helps the PDT develop QC functions for each and helps focus attention to those procedures or tools that may be prone to failure or degradation in the quality of their product(s). The following are key procedures requiring special attention when developing QC programs:

a. Site preparation procedures

b. Data acquisition procedures

c. Data processing procedures

d. Anomaly selection processes

e. Anomaly classification processes

f. Anomaly reacquisition and marking procedures

g. Anomaly excavation and resolution procedures

11.2.1.4. Critical subsystems requiring specific monitoring and/or testing in QC programs include the following:

a. Geophysical instruments

b. Operators

c. Positioning systems

d. Geodetic surveys

11.2.1.5. Once these critical components and their failure modes have been identified, the PDT technical personnel will develop QC methods and measures (or tests) to ensure or demonstrate that the processes, as used by the contractor, achieve project objectives and produce good data. The QC tests and their related failure criteria must be designed specifically to test one or more key procedures or subsystems. Rarely will a single QC test provide a thorough check of all possible failure modes for a given geophysical system. In many instances, two or more QC methods will be used to monitor critical procedures and subsystems. The PDT should verify all QC measures have been implemented and all QC tests meet their pass/fail criteria. Any test that fails should be fully addressed through root-cause analyses and corrective actions before being accepted by the government. Table 11-1 presents common geophysical procedures and their related failure modes.

11.2.1.6. Listed below are elements of critical procedures and subsystems that can be used to define what is meant by “good data.” These elements, if applicable, would be critical to the quality of all geophysical surveys performed to detect TOI. The PDT should determine the frequency any one QC test should be performed to monitor these procedures. Typical frequencies to be considered include beginning of project, daily, start and end of day, start and end of collecting a dataset, per parcel of land basis, and per operator basis (for analog systems).

11.2.1.6.1. <u>Define Geophysical Systems Function Checks</u>. Purpose is to verify the geophysical system has not malfunctioned. Checked by performing repeatability tests, standard response tests, evaluating background noise levels, evaluating positioning accuracies and precisions, and resweeping or digitally mapping sections of analog geophysics lanes.

11.2.1.6.2. <u>Define Survey Coverage Requirements</u>. Purpose is to clearly define overall survey coverage needs for all possible terrain/vegetation/obstruction conditions on site. This topic also must address allowable gaps between adjacent DGM survey lines. Methods of checking coverage include reviewing track plots (non–line-and-fiducial methods), calculating sizes of data gaps, implementing a blind seeding program using small metallic objects, and visual observations of line-and-fiducial, odometer, and analog surveys.

Table 11-1: Common Geophysical Procedures and Their Related Failure Modes

| Procedure | Failure Mode or Cause | Valid QC Checks |
|---|---|---|
| Geophysical mapping, general | Field geophysicist using unauthorized and/or untested equipment and/or unauthorized field procedures | 1. Visual observations<br>2. Verify the QC Plan is specific to the geophysical system(s) accepted/authorized for the project. |
| Instrument set-up | Broken equipment or bad cable connections | 1. Static background test<br>2. Static spike<br>3. Other system-specific function tests<br>4. Personnel tests |
| Geophysical mapping, general | Mapping coverage is not achieving required coverage goals | 1. For analog methods and line and fiducial methods, visual observations<br>2. For digital methods, plot track-plots and review for coverage.<br>3. For digital methods, use automated tools to calculate actual coverage achieved. |
| Line-and-fiducial DGM, odometer trigger mode or time-based trigger mode | Insufficient or excessive measurements accrued along a segment | 1. Check count of measurements at each end-of-line.<br>2. Check distance between along-line readings during post processing.<br>3. GSV blind positioning seeds are detected and included on the dig list. |
| Line-and-fiducial DGM, odometer trigger mode | Data gaps mispositioned (e.g., gaps due to trees or other common obstructions) due to poor procedure or incorrectly entered values during acquisition or post-processing | 1. Measure actual location of gaps in the field and compare to those shown during processing.<br>2. Check track-plot maps for inconsistent along-line measurement spacing on both sides of gaps.<br>3. GSV blind positioning seeds near potential data gaps and confirming seeds are not detected on lines too far from their placement location. |
| Line-and-fiducial DGM, time-based trigger mode | Fiducial marks and/or start or end locations were misplaced during acquisition or incorrectly entered during post-processing. | 1. Create a map showing survey speeds or track-plots to check for line segments with inconsistent velocities or inconsistent measurement spacing.<br>2. Placement of GSV blind positioning seeds and confirming seeds are detected within expected response range and are not positioned on lines too far (laterally) from where they were placed. |
| Line-and-fiducial DGM, odometer and time-based trigger mode | Operator deviates laterally from the planned path. | 1. Visual observation during acquisition<br>2. Placement of GSV blind positioning seeds and confirming seeds are not detected on lines too far (laterally) from where they were placed. |

| Procedure | Failure Mode or Cause | Valid QC Checks |
|---|---|---|
| Line-and-fiducial DGM, odometer and time-based trigger modes | Data mispositioned due to nonsquare grid setup and/or grid dimensions are not as reported | 1. Measure diagonals across grid to confirm 90-degree grid corners.<br>2. Measure lengths of grid boundaries<br>3. Placement of GSV blind positioning seeds and confirming seeds are not detected on lines too far (laterally) from where they were placed. |
| DGM field procedures using automated positioning system | Data mispositioned due to spikes or “erratic behavior” in the positioning solutions | 1. Create a map showing survey speeds and check for areas with inconsistent velocities.<br>2. If available, check positioning solution quality, such as HDOP, number of reference stations or satellites used, signal strength.<br>3. Placement of GSV blind positioning seeds and confirming seeds are not detected on lines too far (laterally) from where they were placed. |
| DGM field procedures using automated positioning systems | Data mispositioned due to incorrectly entered sensor-to-positioning antenna offsets or incorrectly entered positioning system reference coordinates | 1. Place blind seeds throughout survey area and check they are detected within expected accuracies.<br>2. Perform the “clover-leaf” test over a known point(s) and verify the track plots cross at proper coordinates. |
| DGM field procedures using automated positioning systems | Data mispositioned due to incorrect base station coordinates or base station set-up over wrong location | 1. Perform and record daily static positioning checks over known control points. |
| DGM, data processing | Processing yields anomalies with atypical shape characteristics | 1. Visual reviews of DGM maps for anomaly shape characteristics<br>2. Check interpreted locations of QC and/or QA blind seed items.<br>3. Verify sensor to positioning antenna offsets.<br>4. Check latency values used and check for changes in survey speed if simple “lag” corrections are used.<br>5. Collect twice daily IVS tests and confirm anomaly response and target location are within the project’s performance metrics. |
| DGM, anomaly selections | Processing and anomaly selection methods produce excessive anomaly selections and/or anomalies are the result of gridding artifacts. | 1. Visual review and/or automated verification of anomaly proximities<br>2. Overlay track-plots on gridded data to confirm all anomalies are real.<br>3. Check drift corrections or filtering results in high gradient areas. |
| Anomaly reacquisition, general | Low amplitude and/or small area anomalies reacquired beyond their footprint shown on DGM maps. | 1. Define critical search radius (maximum not-to-exceed search radius) to encompass all possible anomaly size scenarios.<br>2. Provide anomaly-specific critical search radius ($R_{crit}$) based on anomaly footprint size. |

| Procedure | Failure Mode or Cause | Valid QC Checks |
|---|---|---|
| Anomaly reacquisition, general | Large and/or high amplitude anomalies reported as no-contact or false-positive. | 1. Define threshold values above which additional reviews and/or field actions are required before being accepted.<br>2. If the reacquisition procedure does not use the exact same instrument model used to detect and interpret anomalies, return to the location with the same model instrument. |
| Anomaly reacquisition, process uses a system with inferior detection capabilities compared to those of the original mapping survey | Wrong anomaly is reacquired. | 1. Define limits for acceptable location offsets between interpreted location and flagged location, based on systems and processes used.<br>2. Compare dig results for each anomaly with the associated geophysical anomaly characteristics<br>3. After excavations, return with original detection system, to original interpreted location, for a portion or all anomalies and confirm no anomalies remain. |
| Analog geophysics (mag and flag operations) | Geophysical anomaly remains after mapping and digging operations are complete; anomaly source is unknown. | 1. Remap a portion or all of the area with a digital geophysical system and/or an analog system.<br>2. Place blind seed items at depths required to be cleared; place blind seed items at locations that are difficult to access. |
| Analog geophysics (mag and flag operations) | Large piece(s) of metal having MEC-like physical characteristics or that could be masking nearby MEC remains after mapping and digging operations are complete. | 1. Remap a portion or all of the area and excavate anomalies to confirm they do not meet failure criteria or to confirm all large pieces of surface metal have no MEC buried beneath them.<br>2. Place blind seed items throughout project area. |
| Analog geophysics (mag and flag operations) | Operator not achieving proper coverage, not using good sweep techniques, or not properly interpreting instrument measurements. | 1. Visual observations<br>2. Resweeping by second party for presence of MEC-like anomalies<br>3. Blind seeding of ISOs to produce verify coverage and detection capabilities of operators. |
| QC tests | Insufficient documentation or documentation not provided to USACE within required deliverable schedule. | 1. Verify PWS/SOW and contract states that QC documentation will be submitted to USACE and the deliverable schedule.<br>2. Ensure USACE has input into required QC documentation.<br>3. Ensure USACE is notified of all root-cause analyses and that USACE has authority to reject incomplete root-cause analyses and/or incomplete corrective actions. |
| Documenting excavation activities and dig results | Incomplete and/or inaccurate information recorded. | 1. Conduct visual observations.<br>2. Review information on recovered seed items.<br>3. Check for consistent nomenclature in reported information. |

11.2.1.6.3. Define Along-Track Measurement Interval Requirements. Purpose is to clearly define along-track data density needs. Methods of checking along-track data density include calculating along-track sampling intervals (digital), calculating instantaneous point-to-point velocities (digital), visual observations (analog), and logging time-in-lane (analog).

11.2.1.6.4. Define TOI Detection and Anomaly Selection Criteria. Purpose is to verify that anomaly selection criteria meet project needs. Criteria typically are defined during project planning. Tested by reviewing documentation of anomaly selection criteria used for each dataset interpreted (digital), blind seeding for TOI detection and anomaly selection using inert or simulated munitions, blind seeding using metallic objects that produce analog detection responses similar to, or identical to TOIs, digitally mapping sections of analog geophysics lanes to prove no TOIs remain, resweeping analog geophysics lanes using analog tools to prove no TOI anomalies remain.

11.2.1.6.5. Define Anomaly Classification Requirements. Purpose is to verify that the selected anomaly classifier puts all TOIs on the dig list. These requirements are checked by setting pass/fail anomaly classification criteria, setting pass/fail criteria for detection and classification of blind seeds, setting pass/fail criteria for anomaly inversion results, setting pass/fail criteria for the inverted offset of the blind seed location, and evaluating the dig results against the anomaly classifier through the feedback process.

11.2.1.6.6. Define Anomaly Reacquisition Requirements. Purpose is to verify detected and selected anomalies are marked for excavation. Anomaly reacquisition requirements are verified by setting pass/fail anomaly repeatability criteria, setting pass/fail maximum allowable offset distances, testing efficacy of procedures for marking all localized anomalies during project planning, and testing implementation of the false positives and no-contacts management plan.

11.2.1.6.7. Define Anomaly Resolution Requirements. Purpose is to verify the excavated item(s) adequately explain anomaly characteristics. This topic also must include criteria for accepting dig results reported as false positives, no-contacts, “geology,” or “hot rocks.” Methods for testing anomaly resolution procedures include defining size/depth/weight criteria for various categories of anomaly characteristics, post-excavation verifications using appropriate geophysical systems, and inspection of dig results and anomaly maps.

11.2.1.6.8. Define PRV Requirements. Purpose is to verify that the remediation process has been effective, such that few if any TOIs might still remain. PRV requirements are established using either anomaly compliance sampling or transect compliance sampling methods and determining the amount of sampling required to meet the project-specific statistical confidence level. The failure criterion for PRV verification is finding TOIs in an area that is presumed to no longer contain TOIs. PRV includes most, if not all, of the processes described above; therefore, the PDT must establish pass/fail criteria for each of the geophysical procedures conducted during PRV, identify their related failure modes, and evaluate the geophysical data to determine if it meets the project’s DQOs.

11.2.1.6.9. Define Process Specific Requirements for Specialized or Unique Processes or Subsystems. Purpose is to verify that procedures specific to a particular system are performed to meet project needs. Examples include defining not-to-exceed survey speeds for systems sensitive to survey velocity, defining specific setup procedures for specialized positioning systems, and defining specialized function check requirements for systems requiring specialized function-checks or calibration.

11.2.1.7. Table 11-1 presents possible failure modes for several key geophysical procedures and key subsystems that are commonly used. The table also includes suggested QC measures that can be implemented to monitor for possible failures.

11.2.2. Munitions and Explosives of Concern Process Quality Performance Requirements.

11.2.2.1. Introduction. Quality standards for geophysical procedures and how they are used are provided in this section. Some typical quality pass/fail tests for geophysical operations are listed below. Each is identified as applicable to digital mapping, analog mapping, or both. In general, pass/fail criteria are quantified or defined for each test performed. A brief description of how each test is implemented also is provided. When a specific test is used, it normally it is tailored to site-specific and contract-specific needs and requirements. Where applicable, pass/fail criteria should be defined based upon the current knowledge of the project site(s). The pass/fail criteria typically would be revised in the event new information about a site is discovered over the course of the project. If the PDT uses the examples below, the example pass/fail criteria must be tailored to project objectives and the geophysical system(s) used.

11.2.2.1.1. Table 11-2 presents the critical performance requirements for RIs and RAs for both digital geophysical and analog systems. These performance requirements require QC processes that the PDT must employ during MR geophysical investigations. Some sites might require additional QC requirements for geophysical operations to ensure project DQOs are met. In addition, the PDT may have additional QC processes within their SOPs, which should be applied whenever applicable.

Table 11-2: Critical Process Quality Performance Requirements

| Process | RI | | RA | |
|---|---|---|---|---|
| | DGM | Analog | DGM | Analog |
| Static repeatability | X | X | X | X |
| Along line measurement spacing | X | | X | |
| Speed | X | X | X | X |
| Coverage | X | X | X | X |
| Dynamic detection repeatability | X | X | X | X |
| Dynamic positioning repeatability | X | | X | |
| Target selection (DGM) / detection and recovery (analog) | X | X | X | X |
| Anomaly resolution | X | X | X | X |
| Geodetic equipment functionality | X | X | X | X |
| Geodetic internal consistency | X | X | X | X |
| Geodetic accuracy | X | X | X | X |
| Geodetic repeatability | X | X | X | X |

11.2.2.1.2. Tables 11-3 through 11-6 (at the end of this chapter) present the specific performance requirements for RIs and RAs for both digital and analog systems. The tables also present the applicability, performance standard, frequency of testing, and consequence of failure of the requirement for each of the respective tests listed in Table 11-2, where applicable. Additional guidance for each requirement is included in the footnotes to each table. These performance requirements and their respective performance standards are applicable directly to geophysical investigations on land using commercially available geophysical instruments (see Chapter 6). These performance requirements can be tailored for underwater operations as well; however, some of the tolerances are less strict and the test often are less frequent.

11.2.2.1.2.1. Advanced EMI Sensors and Anomaly Classification. When advanced EMI sensors are used to classify targets as either TOI or non-TOI, the PDT should consider whether additional performance requirements are required. In particular, in addition to blind seeding the production area with ISOs IAW the GSV process, the PDT should consider emplacing inert munitions as blind seeds within the production site as a QC check on the anomaly classification process. The frequency of the inert munition blind seeding should be commensurate with the frequency for the dynamic detection repeatability test (i.e., one inert munition blind seed per grid or dataset). The performance metric for the blind seed item must be based on the feature parameters (e.g., principal polarizabilities, tau) that are used to classify the anomalies. Any failure to identify an inert munition blind seed will cause that data lot submittal to fail and require a CAR to determine why the classification process didn’t identify the target as a TOI and place it on the dig list. If the missed process causes a change in the parameters or decision logic used to determine whether the anomaly is or is not a TOI, all previously cleared portions of the site may require a reclassification to determine if additional potential TOIs have not been placed on the dig list. At present, research is being conducted to determine effective QC procedures for geophysical investigations that use advanced EMI sensors and classification methods. The following subsections briefly discuss the various QC considerations the PDT should evaluate prior to using an advanced EMI sensor.

11.2.2.1.2.1.1 The PDT should consider how the GSV process, including the IVS and blind seeding approach, will be applied to the project site to perform QC on the anomaly classification process. The PDT should evaluate whether blind seeds will consist of ISOs, inert surrogates of known munitions at the site, and/or inert surrogates of unknown munitions at the site. The blind seeds should be emplaced in a frequency IAW the GSV process (e.g., one seed item per data set), and IVS data will be collected twice daily. The PDT should evaluate the IVS data on a daily basis to determine the RMS errors for each seed item placed in the IVS.

11.2.2.1.2.1.2 The PDT should evaluate the positioning of the advanced EMI sensor over the interpreted target location. Results from ESTCP live-site demonstrations indicate that sensors improperly placed over the target location (i.e., the buried metallic object is close to the edge of the advanced EMI sensor coil) can lead to poor data inversions and classifications (Harre, 2011). The PDT should determine the interpreted target location offset threshold above which the advanced EMI data is re-collected. For example, the PDT may determine that all offsets between the inverted item location and the center of the sensor that are greater than 0.4 m will be re-collected or automatically placed on the dig list, whichever is more economical.

11.2.2.1.2.1.3 The PDT must assess that each transmitter and receiver coil was operating within tolerable limits during the advanced EMI data collection. Data from live-site demonstrations indicate that a single, poorly operating transmitter or receiver coil can have significant effect on the data inversion and classification results. The PDT should re-collect advance EMI data for all anomaly locations for which coils were not operating within limits or place the anomalies on the dig list, whichever is more economical.

11.2.2.1.2.1.4 The PDT should visit the SERDP-ESTCP Web page (http://www.serdp.org/) frequently to keep abreast of advances in the QC methods for these sensors.

11.2.2.1.2.2. Underwater Investigations. Although the performance requirements in Tables 11-3 through 11-6 are designed for geophysical investigations on land, they may be applied to underwater investigations as well. However, various factors unique to the underwater environment (e.g., less accurate positioning, decreased ability to maintain a constant altitude above the sediment surface, greater distance between the sensor and the metallic item) make it difficult for the geophysical systems' ability to meet the same performance standards defined for land-based investigations. Therefore, the PDT must determine the performance standards that are most applicable to the site given the site conditions, how the data will be used, how the investigation is performed, and what corrective measure should be implemented if the geophysical system fails to meet the performance standard.

11.2.2.2. QC and QA Statements. This subsection presents common QC and/or QA statements that define additional performance standards not included in Tables 11-3 through 11-6. These statements are not required on all projects; however, they likely will increase the QA/QC standard for the project. Therefore, the PDT should strongly consider adding these additional performance standards to the project QC plan.

11.2.2.2.1. DGM maps shall represent as best as possible the actual potential field as it existed at the time of data collection. This statement is applicable to DGM. Tests associated with this statement are incorporated into the UFP-QAPP. This statement is intended to capture all typical field and processing steps needed to address known failure modes common to most geophysical systems. Tests include checking that all measurement positioning corrections (latency and sensor offset corrections) are implemented, diurnal corrections (for magnetics) are performed, repeatability tests are successful, sensor response tests (commonly referred to as the "spike" test) are within tolerance, personnel tests are successful, noise level tests are successful, drift corrections are properly applied, and cable tests are successful. Failure of any one test typically results in either reprocessing the data or recollecting the data. The reader is referred to the Ordnance and Explosives Digital Geophysical Mapping Guidance – Operational Procedures and Quality Control Manual (USAESCH, 2003) and Quality Assurance Made Easy: Working With Quantified, Site-Specific QC Metrics (Proceedings of the UXO/Countermine Forum, 2004) for more details and examples of how these individual QC tests are designed and implemented.

11.2.2.2.2. Discovery of undocumented or unresolved nonconformance or noncompliance as defined in the accepted QC plan. This performance standard is applicable to DGM and analog mapping. Tests associated with this statement typically are incorporated into the QA program. The purpose of this statement is to clearly assure that the contractor shall be responsible for performing and documenting all tasks required in the QC program. This test usually is performed by reviewing some or all of the contractor's QC documentation for thoroughness and completeness. Failure of the contractor to detect a failed QC test or failure of the contractor to have initiated a root-cause analysis after detecting a QC failure normally results in the government's rejecting all associated work products until all required QC tasks are complete. QC pass/fail criteria should be developed, as applicable, for each QC test specified in the QC plan. Table 11-1 presents examples of common QC tests currently used.

11.2.2.3. Example Quality Standards for Anomaly Resolution Procedures and How They are Used. Anomaly resolution should be performed at all project sites to verify that the excavation of anomalies successfully removed the anomaly identified with the original sensor. The post-excavation anomaly resolution should be conducted with the same geophysical sensor as the original DGM or analog investigation. Anomaly resolution should be conducted IAW Tables 11-3 through 11-6, and the amount of anomaly resolution required for each dataset collected during a geophysical investigation should be based on Table 6-6.

11.2.2.3.1. Typical quality pass/fail tests for anomaly resolution activities are listed below. Each is identified as applicable to digital mapping, analog mapping, or both. A brief description of how each is implemented also is provided. When any specific test is used, it normally would be tailored to site-specific and contract-specific needs and requirements. Where applicable, pass/fail criteria should be defined using current knowledge of the project site(s). The pass/fail criteria typically would be revised in the event new information about a site is discovered over the course of the project. These tests would be designed around how the contractor performs their anomaly resolution processes. Those processes should be capable of successfully excavating or otherwise positively resolving all anomalies tabulated on dig lists or anomalies identified during analog mapping. The purpose of the contractor's QC plan for anomaly resolution should be to define what is meant by "resolved anomaly" and verify each anomaly is unambiguously resolved. The contractor's UFP-QAPP should include a detailed plan for managing anomalies reported as false positive, no contact, hot rock, or geology. If the PDT uses the examples below, the example pass/fail criteria must be tailored to project objectives and the procedures used.

11.2.2.3.2. Note: For most analog mapping projects, the government's QA tasks can be simplified by requiring the contractor to leave the lane markers in the grid until all field-level QA is complete. For all projects, the government's QA tasks can be simplified by requiring the contractor to flag all excavated locations and to leave all flags in the excavated location until field-level QA is complete. Where appropriate, the flags should be labeled with the unique anomaly identifier.

11.2.2.3.2.1. Discovery of an unresolved anomaly listed on a dig list or at a location previously identified during analog mapping operations. This test is applicable to both DGM and analog geophysical systems. The term unresolved is defined as 1) a geophysical signature of unknown source is still present at a location specified on a dig list or an excavated location after it has been declared complete and accepted through the project QC program or 2) an anomaly is reported as no contact, false positive, hot rock, or geology but does not meet the requirements for such under the management plan for reporting the false positives, no contact, hot rock, and geology. Tests associated with this statement normally are incorporated into the QA program.

Tests for case (1) typically would be based on QA inspections at locations tabulated on dig lists. Anomalies at such locations having characteristics associated with MEC buried at depths where their response is at least five to seven times, or more, the background RMS, for which the source is not known, would result in failure. Tests for case (2) normally would involve reviewing some or all anomalies reported as false positive, no contact, hot rock, or geology for compliance with project-specific criteria. Failure of the contractor to unambiguously resolve anomalies likely would result in the government's rejecting all associated work products until all associated root-cause analyses are complete and all corrective actions have been performed.

11.2.2.3.2.2. Discovery of undocumented or unresolved nonconformance or noncompliance as defined in the accepted QC plan. Applicable to DGM and analog mapping. Tests associated with this statement typically are incorporated into the QA program. The purpose of this statement is to clearly assert the contractor shall be responsible for performing and documenting all tasks required in the QC program. This test usually is performed by reviewing some or all of the contractor's QC documentation for thoroughness and completeness. Failure of the contractor to detect a failed QC test or failure of the contractor to have initiated a root-cause analysis after detecting a QC failure likely would result in the government's rejecting all associated work products until all required QC tasks are complete. QC pass/fail criteria should be developed, as applicable, for each QC test specified in the QC Plan. Table 11-1 presents QC tests currently required.

11.2.2.3.2.3. Verification of excavated anomaly locations using geophysical sensors to confirm anomalies are resolved. Applicable to DGM and analog mapping. This is similar to Section 11.2.2.3.2.2. Tests associated with this statement normally are incorporated into the QC and/or QA program. Tests normally would be based on finding unresolved anomalies during QC or QA inspections using geophysical sensors. For this test, unresolved is defined as a geophysical sensor still detects an above background signal over an excavated location and that signal has characteristics similar to those of MEC. Failure of the contractor to unambiguously resolve anomalies likely would result in the government's rejecting all associated work products until all associated root-cause analyses are complete and all corrective actions have been performed.

11.2.2.3.2.4. Verify dig result findings are reviewed and approved by a qualified geophysicist. Applicable to DGM and analog mapping. Tests associated with this statement normally are incorporated into the QC and/or QA program. Tests for this activity may be similar to those for Section 11.2.2.3.2.1, as these are related topics. Tests typically would focus on confirming the descriptions of items recovered during anomaly excavations adequately explain the anomaly characteristics observed in the geophysical data. Tests also would involve reviewing the reported excavation results for compliance with management plan for reporting findings of false positives, no contacts, hot rocks, and geology. Tests also may include reviewing reported information for compliance with standardized reporting nomenclature. Failure of the contractor to verify reported dig findings likely would result in the government's rejecting all associated work products until all associated root-cause analyses are complete and all corrective actions have been performed.

11.2.3. Munitions and Explosives of Concern Product Quality Management.

11.2.3.1. Introduction. The PDT must define what the project-specific final products will be and what results must be achieved for each. The PDT then will need to determine how best to assess the quality of those products. There are two types of products produced from geophysical surveys for MEC projects: tangible products, such as reports and UFP-QAPPs, and intangible products, such as instrument interpretations and declarations that work in a parcel is complete.

11.2.3.2. Common Tangible Geophysical Products and Related Standards. Listed below are common tangible products that can be included in the geophysical quality management programs:

a. Complete MEC UFP-QAPP

b. Complete IVS reports

c. Complete geophysical investigation reports

d. Fully completed dig sheets

e. Properly formatted and documented geophysical data

f. Legible and complete maps showing the geophysical survey's results and interpretations

g. Fully supported anomaly selection criteria and decisions

h. Completed QC reporting

11.2.3.2.1. Quality standards for the products listed above normally would include adherence to standard reporting formats, as specified by the base contract, and completeness requirements and may include requirements that documents be legible, concise, and accurate and use proper grammar. For completed dig lists, acceptance sampling using Table 6-6 or guidance from MILSTD-1916 can be used for verification purposes. This would require returning to a prescribed number of anomaly locations to confirm those anomalies are indeed resolved. The reader is referred to MILSTD-1916 for detailed guidance on acceptance sampling. For most cases, the government would not accept a tangible product that does not meet a quality standard (as defined by the PDT and/or in the SOW/PWS) until all deficiencies have been corrected.

11.2.3.2.2. For removal or remedial actions, the PRV tool can be used to determine whether a parcel of land, or lot, has been remediated to an acceptable standard. If TOIs are identified during the PRV process, the original geophysical data would require review to determine why the TOI was missed during the initial investigation.

11.2.3.3. Common Intangible Geophysical Products and Related Standards. Listed below are intangible products from MEC projects that may be included in the geophysical quality management program:

11.2.3.3.1. One or more parcels of land declared clean or declared as meeting project objectives, also referred to as "QC Complete, turned over to the Government for QA acceptance"

11.2.3.3.2. Geophysical interpretations based on professional judgment, sometime also referred to as manual interpretations

11.2.3.3.3. QC and QA of these products often take the form of verification/acceptance sampling. In this context, verification/acceptance sampling is defined as any procedure used to validate a product after it has been turned over for government acceptance. Typical procedures currently include digitally mapping or remapping (to include resweeping for analog approaches) a portion of an area after it is declared free of MEC contamination. These current verification/acceptance sampling methods are based on performing post-dig anomaly verification sampling as part of the anomaly resolution process. Table 6-6 shows the acceptance sampling criteria for anomaly resolution that PDTs should use to determine the amount of anomalies that must be resolved to achieve a specific confidence level that less than a certain amount of anomalies remain unresolved after investigation. The failure criteria must be the discovery of unresolved or undetected MEC-like geophysical anomalies. Remapping small subportions of a site without a statistically valid reason to do so does not provide statistically significant information regarding the success or failure of an intangible analog or digital geophysics product. Failure criteria must factor for unresolved or undetected MEC-like anomalies. If not, they provide little confidence in the product when such MEC-like anomalies are detected.

11.2.3.3.4. If the PDT chooses to use remapping as a verification/acceptance sampling tool for QC or QA, they should do so only when process QC has a reasonable expectation of delivering uniform products and the PDT agrees on the definitions of production units and lot sizes. The terms production units and lot sizes are terms defined in MILSTD-1916; however, the reader is cautioned that statistically valid definitions for production units or lot sizes of intangible geophysical products are under discussion within the MR community as of the date of this publication. The reader should contact the EM CX for up-to-date information on this topic.

11.2.3.3.5. It is further emphasized that remapping of land parcels mapped using analog geophysical system should have failure criteria defined in terms of previously undiscovered or unidentified MEC-like geophysical anomalies and not in terms of physical sizes of excavated objects. The reason this type of failure criteria is required is that the presence of such anomalies indicates either the analog geophysical mapping interpretations or coverage do not meet project objectives or that instruments malfunctioned. If unexplained MEC-like anomalies are detected, a product failure exists. For properly designed QC plans of analog systems, a mechanism is needed within the UFP-QAPP for either removing all recovered MEC-like anomaly sources from the project site or identifying them as previously discovered. This can be achieved by leaving pin flags at each such location, painting each item recovered, or specifying that any item discovered shall be left on the ground surface. This latter approach would prove difficult to implement if the density of such items is high and may mask subsurface MEC still present or if digital mapping techniques are used for QC or QA and the density of surface metal is high.

11.2.4. Managing Munitions and Explosives of Concern Quality Control Failures.

11.2.4.1. This subsection introduces the topic of managing QC failures and presents ideas of how to establish the meaning of QC failures. Because no geophysical system can guarantee all MEC are detected under all conditions, the PDT should agree upon specific understandings of what a given QC failure indicates upfront. Not all QC failures indicate a breakdown in field processes or that defective or nonconforming products will result; sometimes they simply indicate local site conditions are less amenable to detecting MEC than others. In all instances, the QC personnel should perform a root-cause analysis and determine to what degree the QC failure affects project decisions. QC failures that do not affect project decisions are less significant than those that directly impact project decisions.

11.2.4.2. This subsection provides some examples of how some QC criteria can be managed under different conditions. The list below is not all-inclusive. The PDT should review each QC test included in the QC plan and outline a plan for managing failures in the event they occur. It may be beneficial to identify those types of failures that are minor in nature, those that are critical in nature, and those that could be either minor or critical depending on how they will affect project decisions.

11.2.4.2.1. Undocumented Survey Coverage Gap Too Large. For many characterizations, the important factor is acreage investigated. If some datasets have gaps larger than those acceptable to the PDT, simply surveying an extra grid or transect may suffice, rather than needing to reoccupy small gaps in multiple grids or transects, which can be costly and time consuming. For response actions, the gaps need to be surveyed properly. Root-cause analyses normally focus on the source of the gap to determine if it is due to instrumentation (which is often visible in the track-plot maps), due to a breakdown in following field procedures (the track-plots are accurate, the data were simply collected along the wrong lines), or due to undocumented obstacles. Gaps due to documented obstacles, such as trees or fences, should be addressed during project planning.

11.2.4.2.2. Along-Track Data Density Does Not Meet a Project Objective or Metric. In circumstances where no anomalies are detected in the affected area, the project needs may not warrant spending the time to correct this failure, as it would not impact PDT decisions. If anomalies are present on the affected portions, these types of failures likely would not be allowed and appropriate actions would be required. Root-cause analyses would be similar to those described in Section 11.2.4.2.1.

11.2.4.2.3. Contractor Fails to Detect a Seeded Anomaly. Some blind seed items may go undetected if they are buried at depths difficult for the geophysical system to detect. This should be avoided to the practical extent possible by placing the blind seeds at depths that ensure 100% detection IAW the GSV process. If the blind seed item is still not detected and if all other data quality tests and system checks indicate the data are of high quality, it may not be possible to reliably detect that seed item under the conditions it is buried in. In this circumstance, the PDT should be notified of the failure, as it may affect the project's detection capability objectives or PDT expectations. Root-cause analyses typically focus on reviewing the geophysical and related QC data and reviewing the anomaly detection and selection criteria. They may include re-collecting data over the location to confirm it indeed could not be detected.

11.2.4.2.4. Contractor Fails to Include a Seeded Inert Munition on their Anomaly Classification Dig List. If the anomaly classification feature parameters indicate that the anomaly is a likely non-MEC and the item is placed on the do-not-dig list, the contractor must perform a root-cause analysis to determine why the inert munition was not placed on the dig list. If the root-cause analysis determines that the inert munition has characteristics that are significantly different than the MEC for which it is a surrogate, then the classification decision logic should be adjusted to account for the actual feature parameters for the MEC. If the root-cause analysis determines that the inert munitions item has feature parameters that are close to the MEC of interest, the PDT should determine if modifications to the classification decision logic needs to be modified. If the goal of the investigation is to remove all MEC within the production area, then the classification parameters need to be modified to ensure that all MEC are identified and excavated. If the goal of the investigation is to determine whether MEC are present within a sector, the classification parameters may not need to be modified if all other QC parameters met the pass/fail criteria.

11.2.4.2.5. Calculated Background Noise Levels for a Dataset Exceed a QC Threshold. It is common for background noise levels to change over a project site. Normally, this metric is used as an indicator that instrument platform integrity is degrading or that instrument failure may be occurring. The root-cause analyses typically focus on reviewing the affected dataset(s) and associated areas for abnormal measurement spikes (indicative of degrading instrument platform integrity or instrument failure), local terrain conditions, local geology conditions, or an increase in clutter due to proximity to a target area. If local terrain, geology, or clutter is suspected, the analyses normally include recollecting small amounts of data in one or more affected datasets to prove the increased noise levels are repeatable. If the increased noise levels are reproduced, adjusting the threshold upward for such areas may be warranted. If they are not reproduced, then either problems with the integrity of the instrument platform are the cause or instrument failures occurred.

11.2.4.2.6. Anomaly Reacquisition Team Reports a False Positive for a Large Amplitude Anomaly or Anomaly Resolution Team Reports a Small Piece of Metal for a Large Amplitude Anomaly. For site characterizations, a small number of such failures may be acceptable, particularly if returning to the anomaly location for more thorough excavations would not affect project decisions. Such a scenario would exist if the anomaly is located in an area already confirmed as being contaminated with MEC or if large numbers of surrounding anomalies are reported as unrelated to DoD activities and there is reasonable statistical justification that the missed anomaly is not MEC or MEC-related. In these circumstances, even though the failure indicates a possible significant process failure or possibly a significant instrument failure, returning to the actual anomaly would not affect decisions for that area. For response actions, these types of failures likely would not be allowed and appropriate actions would be required for each such anomaly. Root-cause analyses should focus on the procedures the contractor uses to document excavation results and how that information is provided, reviewed, and accepted by geophysical and QC personnel.

11.2.4.2.7. QC Mapping. QC mapping (using either digital or analog systems) of an analog geophysics lane detects an undocumented or previously undiscovered MEC-like geophysical signal. Since analog systems benefit only from being able to differentiate between very small and shallow anomaly sources from very large and deep sources, most signals must be excavated in order to determine if the source is MEC or not. If, during a QC resweep, a signal is detected that must be excavated to determine if it is MEC or not, the finding indicates a significant failure in how the analog geophysical system was used to detect MEC. For characterization surveys, this finding may not be significant for the same reasons explained in Section 11.2.4.2.5. Similarly, for response actions, this finding likely would constitute a significant failure requiring appropriate actions be taken. Root-cause analyses focus on why the operator's interpretation of his or her geophysical instrument was in error, why their coverage of their lanes does not meet project objectives, or if their geophysical sensor failed. Typically, the analyses include reviewing field logs for discrepancies, interviewing the responsible team leader, and resweeping the affected area or all lanes mapped by the responsible individual(s).

11.2.4.2.8. A QC Function Check Exceeds a QC Threshold. Most QC function checks are designed to demonstrate whether the instruments are functioning properly or not. If all reviews of the associated data and all other function checks indicate proper instrument functionality, then the QC failure is not likely to affect project decisions. The root-cause analyses typically include reviewing all associated data for indications of instrument failure and all other QC function check results for evidence of instrument failure and how the field team implements the QC function check procedures. The analyses also may include recollecting data over small portions of associated areas to prove whether or not instrument failure occurred.

11.2.5. Special Considerations for Munitions and Explosives of Concern Quality Control Programs.

11.2.5.1. MEC Characteristics and Burial Characteristics that Affect QC.

11.2.5.1.1. The characteristics of the target MEC and how it could be buried must be factored into the QC plan. For example, most MEC have shapes that are axially symmetric, similar to tear drops (mortars and bombs), elongated egg-like shapes (MK2 grenades), circular or dumbbell shaped (rockets), or bullet shaped (large caliber projectiles). These types of items produce responses with very different SNRs in most detectors when they are buried at different angles but at the same depths. For instance, most commonly used horizontal-loop TDEMI detectors can detect most projectiles at much greater depths when buried in a vertical orientation as opposed to a horizontal orientation. What this means is that a MEC item that may go undetected at one depth when buried in one orientation will produce a high SNR and be easily detected if buried in another orientation at the same depth. For this reason, QC inspections should focus not only on the physical size of items recovered but also should focus on the instrument measurements recorded or observed during the QC inspections.

11.2.5.1.2. The UFP-QAPP must differentiate between detection capabilities and task results. The term "task results" refers to results from all field activities associated with the detection and removal of MEC and includes geophysical mapping, anomaly reacquisition, and anomaly resolution. Therefore, the UFP-QAPP must factor in the limitations of the geophysical system to effectively detect all MEC as stated in the project objectives. Essentially, the UFP-QAPP must differentiate quality elements that define what is meant by "good data" from quality elements that are affected by technology limitations. As an example, the UFP-QAPP may need to differentiate MEC anomaly characteristics that must always be detected from those that may sometimes go undetected or unselected. For the former, QC measures are developed to verify all such signatures are detected and selected. Finding such a signature during QC inspections would strongly suggest a major defect in work task products. For technology limitations, QC measures focus on how project decisions are made, and finding such signatures during QC inspections may or may not suggest defects in work task products. As an example, if a weak anomaly is detected that may be MEC or may be geologic noise turns out to be MEC, then finding such a signature during QC inspection suggests either a product defect or a limitation of the technology. It would be deemed a product defect if, during the root-cause analysis, it is found the quality of the underlying geophysical data does not meet project needs (such as having too many data gaps or the sensor noise levels are too high and could have been reduced). If, on the other hand, the quality of the data is good, then finding a MEC item suggests not all project objectives can be achieved using current technologies because the probability of detecting that MEC under those site-specific conditions is less than 1. Another possibility in this scenario is that the project decision criteria are not sufficiently stringent to meet all project objectives (i.e., the anomaly selection criteria were set too high) and more anomalies with lower signals must now be selected using adjusted criteria. Whatever the cause of quality failures, whether related to data quality or technology limitations, root-cause analyses will be system-specific and should be thorough. The government geophysicist should verify that all possible causes of the failure have been identified and, if appropriate, each is tested to confirm or refute each possibility. As an example, one common QC test used to monitor sensor performance is to quantify the variations in background measurements by calculating their standard deviation. This metric is used as one of several means to monitor for instrument malfunction, and QC pass/fail criteria typically are established using IVS data at a time when the sensor was proven to be functioning properly. However, as site conditions vary, often as the areas surveyed approach a target zone or the underlying geology changes, the calculated background variations increase to the point where the noise pass/fail test fails. The root-cause analysis likely include testing system cables for shorts and testing sensors for broken components or bad connections; if no obvious sources are found and geology or site conditions are suspected, the sensor likely would be redeployed over the area to confirm the increased noise levels are reproduced. If confirmed as such, the corrective actions likely would be limited to adjusting anomaly selection criteria to factor for increased noise levels in affected areas.

11.2.5.2. <u>MEC Detection Variables that Affect QC</u>.

11.2.5.2.1. The types of issues presented in Section 11.2.5.1.1 stem from the fact that most production-level DGM detectors can only reliably classify large TOIs from small pieces of clutter. If small TOIs are anticipated on an MRS that also has similarly sized clutter, then these sensors are less reliable at differentiating between the small TOIs and clutter. This is not true of advanced EMI sensors, which have shown significant capability to distinguish small TOIs (e.g., 37 mm projectiles, small ISOs) from small non-TOI items at several test sites (see www.estcp.org for additional information on classification studies). If advanced EMI sensors are not used to classify anomalies and because production-level DGM surveys cannot differentiate between non-MEC geophysical signatures and MEC signatures, all such signatures must be investigated. More importantly, these are the types of anomalies that should not be present in any post-removal QC or QA inspection or post-removal verification data.

11.2.5.2.2. For each type of MEC, the project team should define anomaly characteristics that always must be detected. Many MEC are sufficiently large that, under certain burial conditions, they always produce anomalies with unambiguous characteristics. Here the term unambiguous normally is associated with high SNR, high peak amplitude, and/or large spatial area of above-background measurements. Other clearly definable, instrument-specific characteristics also can be used. Anomalies having signatures with these characteristics represent buried target items that may or may not be MEC. MEC associated with such anomalies almost always are buried at depths shallower than the maximum detection depth the geophysical system is capable of detecting. The PDT must decide which anomaly characteristics constitute a process failure if they go undetected or unresolved and also must agree that anomalies with other characteristics may be present in QC, QA or post-verification data, even if those other characteristics sometimes can be associated with MEC. These latter characteristics usually are associated with MEC that are buried at depths or orientations that are difficult to detect with certainty and are commonly referred to as difficult to detect anomalies or anomalies near the LOD for a given geophysical system.

11.3. Munitions Constituents Quality Management.

11.3.1. Uniform Federal Policy - Quality Assurance Project Plan. The contractor must ensure that adequate quality controls are performed for the various MC analytical tasks performed. The contractor is responsible for achieving data quality criteria to meet the project DQOs and should document these in the UFP-QAPP. The UFP-QAPP should document in detail the QA and QC and other technical activities to ensure that the environmental data collected are of the correct type and quality required for a specific decision. The government may reject analytical data that do not meet QC requirements. Additional guidance for UFP-QAPPs is provided in Section 4.4.

11.3.2. Data Quality. The contractor must provide data quality of a level sufficient to ensure the production of high quality chemical data that satisfy the project-specific DQOs.

11.3.2.1. ER 200-1-7 is the umbrella USACE document that defines Chemical Data Quality Management activities and integrates all of the other USACE guidance on environmental data quality management. Its purpose is to assure that the analytical data meet project DQOs, which are documented along with the required QC criteria in the approved project UFP-QAPP.

11.3.2.2. EM 200-1-2 provides guidance for designing data collection objectives, identifying data need and designing data collections programs. See Chapter 2 for further details on the TPP process applied to MR projects.

11.3.2.3. USACE guidance for reviewing data packages and qualifying data for performance-based methods, such as SW-846 method, is provided in EM 200-1-10, Guidance for Evaluating Performance-Based Chemical Data, 30 Jun 05. EM 200-1-10 provides guidance for the USACE and USACE contractors for evaluating instrumental chemical data using a performance-based approach. A performance-based method is defined as an analytical procedure for which data quality indicators are documented and evaluated with respect to acceptance criteria that are established from project data quality objectives. In particular, the PARCCS parameters (precision, accuracy, representativeness, completeness, comparability, and sensitivity) are documented for the target analytes of concern at the levels of concern (i.e., at or below project action levels) in the environmental media of interest and are evaluated with respect to acceptance limits or MQOs that are designed to ensure that total measurement uncertainty is within the limits prescribed by project DQOs. The extent of data review is dependent upon the project's DQOs and the type of data. For example, the reporting and evaluation requirements are different for definitive data and screening data.

11.3.2.3.1. A performance-based review typically includes the evaluation of the following QC elements:

- Completeness
- Holding time and preservation
- Initial calibration
- Initial calibration verification
- Continuing calibration certification
- Sensitivity (e.g., detection and quantitation limits)
- Blanks (e.g., field and method blanks)
- Laboratory control samples (LCSs)
- Post-digestion spikes (PDSs; for trace metal methods)
- Matrix spikes (MSs)
- Matrix spike duplicates and matrix duplicates
- Surrogates (for organic chromatographic methods)

11.3.2.3.2. See Section 13.8.3.1.1 and ER 200-3-1, Environmental Quality - Formerly Used Defense Sites (FUDS) Program Policy, 2004 for a discussion of Staged Electronic Data Deliverables (SEDD) and the requirements for electronic data deliverable review. The USEPA CLP National Functional Guidelines for Data Review and USEPA regional guidance for data validation also may be applicable to a specific project.

11.3.3. Quality Control. QC samples are designed to evaluate the PARCCS parameters and identify quality problems in laboratory analytical performance, matrix effects, and in field performance. For example, accuracy is assessed from calibration, LCSs, MSs, PDSs, and surrogate data. Precision is evaluated from duplicate laboratory control and MS samples. Sensitivity is evaluated using LODs and LOQs. Representativeness is evaluated via the review of holding time and blank data. A laboratory's analytical performance is evaluated using calibration results (i.e., initial calibrations, initial calibration verifications, and continuing calibration verifications) and batch QC samples such as method blanks and LCSs. Matrix effects are evaluated using MS, surrogate spike, and PDS recoveries. Field duplicates, rinsate blanks, and trip blanks are examples of QC samples that are employed to assess QC problems associated with sample collection activities. The QC samples should include all sample matrices and analytical parameters except disposal parameters (i.e., TCLP, reactivity, corrosivity, and ignitability). The contractor should administer all QC sample handling and custody requirements in a similar manner to that used for the environmental samples.

11.3.4. Laboratory QC. Laboratories selected to provide chemical data for USACE munitions environmental projects must have a quality system. The laboratory's quality system is the process by which the laboratory conducts its activities so as to provide the client with data of known and documented quality with which to demonstrate regulatory compliance and for decision-making purposes. The laboratory must be accredited for the chemical analyses being performed through the DoD ELAP. The guidance for quality systems that environmental testing laboratories must follow can be found in the DoD QSM for Environmental Laboratories. This guidance is based on the National Environmental Laboratory Accreditation Conferences Quality System requirements, which is consistent with ISO/IEC 17025:1999 and provides implementation clarification and expectations for DoD environmental programs. It is designed to serve as a standard reference for DoD representatives, including contractors who design, implement, and oversee contracts with environmental testing laboratories. The DoD QSM includes detailed DoD-specific laboratory QC requirements and acceptance limits for USEPA SW-846 methods, which must be followed by the laboratory for munitions projects. Laboratory QC requirements should be discussed with laboratory personnel during project planning.

11.3.5. Coordination with QA Laboratory. If contractual requirements specify the collection of QA split samples, the contractor is required to provide coordination of the collection and transportation of the QA samples to the QA laboratory acquired per the requirements specified in the SOW/PWS. The PDT should determine the rate per matrix per analysis per sampling event for the QA splits. QA samples should be taken as splits of the same samples as QC duplicates (i.e., sample should be homogenized and split in triplicate). If sampling and analysis of volatile organic compounds is required for an MC site, the QA split should be collocated. The QA split samples should include the same matrices and parameters as QC duplicate samples. The QA laboratory should be provided a list of the applicable MQOs. The MQOs should include, but should not be limited to, identification of extraction and analysis method numbers and a list of analytes with required limits. All QA sample handling and custody requirements should be administered by the contractor similar to the environmental samples. See EM 200-1-6, Chemical Quality Assurance for Hazardous, Toxic and Radioactive Waste (HTRW) Projects (http://140.194.76.129/publications/eng-manuals) for additional guidance.

11.3.6. Performance Evaluation (PE) Samples. EM 200-1-7, Environmental Quality Performance Evaluation (PE) Program, 1 Feb 01, provides guidance for the use of PE samples as a tool for evaluating analytical laboratory performance. If PE samples will be employed for a project to validate laboratory performance, determine the use of the PE samples early in project planning to allow adequate time for selection and design of the samples. Clear goals for PE samples should be designed around the project's analytical needs and DQOs. The use of project-specific PE samples is ideal; however, they may not be cost effective, timely to produce, or available.

11.3.7. Considerations during IS.

11.3.7.1. Refer to published guidance for IS (see Section 8.8.1.3.2.1) for detailed information on the special QC requirements for IS. Field replicates provide a measure of the variability or total error of the data set (field sampling error + laboratory sample processing and subsampling error + laboratory analytical error). Field replicates for IS are not field splits; rather, they must be independently collected incremental samples from the same sampling unit. Reproducibility of IS results by replicate sampling is key to demonstrating that data are scientifically defensible and representative and the only means by which confidence can be quantified. Detailed laboratory QC requirements for IS samples for explosives by Method 8330B can be found in DoD QSM Version 4.2. For soil samples, QC samples, including LCS and MS samples, must be ground and subsampled in the same manner as the field samples to ensure the accuracy of the data.

11.3.7.2. Data from a poorly conceived or poorly executed IS sampling program may not be acceptable because project objectives and DQOs were not clearly defined and the data cannot properly inform the decision to be made. Some project team members or stakeholders may be concerned that the mean concentrations obtained by IS do not provide spatial information on the distribution of contaminants within a sampling unit. A project team needs to be prepared to address concerns regarding IS diluting out hotspot contamination, as well as not obtaining information about the spatial distribution of contaminants within a single sampling unit.

11.4. Geospatial Data and System Quality Control.

11.4.1. The primary goal of data quality management is to ensure a consistent and measurable accuracy throughout the database. Consistency is achieved through the use of documented, approved production procedures. Data handling and management should be consistent with, and refer to, the project's UFP-QAPP. Following production, an assessment of the quality of the data set should be conducted to measure the level of achievement of the expected results.

11.4.2. The PDT should establish the level of production control and rigor with which quality assessments should be made consistent with the project-specific GDS requirements. GDS with stringent accuracy and consistency requirements may need to have detailed procedural documentation, a completion signature for each production step, and a comprehensive assessment of accuracy. Conversely, smaller-scale GDS developed for production of background geospatial data may have much less stringent production documentation requirements and only a cursory accuracy assessment.

11.4.3. The PDT should state in the SOW that the contractor should perform QC of the GDS activities and products and include independent tests, which may be reviewed periodically by the government. Therefore, USACE QA and testing functions will focus on whether the contractor meets the required project requirements.

Table 11-3: Performance Requirements for RIs Using DGM Methods[a]

| Requirement | Applicability (Specific to Collection Method/Use) | Performance Standard | Frequency | Consequence of Failure[b] |
|---|---|---|---|---|
| Static repeatability (instrument functionality)[c] | All | Response (mean static spike minus mean static back ground) within +/- 10% | Min 1 daily | Day's dataset fails unless seed item is mapped that day with repeatable anomaly characteristics (see dynamic detection repeatability). |
| Along-line measurement spacing | All | 98% <= 25 cm along line[d] | By dataset | Dataset submittal fails. |
| Speed | Transects [e] | 95% within maximum project design speed or demonstrated speed | By dataset | Dataset submittal fails unless new maximum speed successfully demonstrated at IVS. |
| Coverage * | Grids | > 90% coverage at project design line spacing and 98% coverage at 1 meter line spacing[f] | By dataset or grid[g] | Submittal fails unless gaps filled, additional data collected, or government refund for missing acreage. |
| Dynamic detection repeatability (IVS and GSV blind seeding) | IVS (applies to grids and transects)[h] | Peak response repeatable to +/- 25% of expected response[i] | Twice daily. | Submittal fails. |
| | Blind Seeds (applies to grids and to transects with intrusive) | Peak response > 75% of minimum expected response[i] | 1 per day per team based on expected production rate | Submittal fails. |
| Dynamic positioning repeatability (IVS and GSV blind seeding) | IVS (applies to grids and transects) | Position offset of seed item targets <= 25 cm | Twice daily | Submittal fails. |
| | Blind seeds (applies to grids) | 90% positioning offset is <=25 cm + ½ line/sensor spacing and 100% is <=35cm + ½ line/sensor for digital positioning systems (<=50cm + 1/2 line spacing for fiducially positioned data) OR the positioning DQO required for site specific tasks[j] | 1 per day per team based on expected production rate | Submittal fails. |

| Requirement | Applicability (Specific to Collection Method/Use) | Performance Standard | Frequency | Consequence of Failure[b] |
|---|---|---|---|---|
| | Transects with reacquisition/digging | Position offset of seed item targets <= 1 meter | 1 per day per team based on expected production rate | Submittal fails. |
| Target selection | All | All dig list targets are selected according to project design | By grid or dataset[g] | Submittal fails. |
| Anomaly resolution*[k] | Verification checking by DGM remapping[l] or verification checking with original instrument of anomaly footprint after excavation[m] | Second party checks open holes to determine:<br>90% confidence < 5% unresolved anomalies[n]<br>Accept on zero. | Rate varies depending on lot size[o]. See Table 6-6: Acceptance Sampling Table for Anomaly Resolution.[p] | Lot submittal fails. |
| Geodetic equipment functionality* | All | Position offset of known/temporary control point within expected range as described in the approved UFP-QAPP[q] | Daily | Redo affected work or reprocess affected data. |
| Geodetic internal consistency | Grids with line-and-fiducial positioning | Grid corners are internally consistent within 30 cm on any leg or diagonal. | Per grid | Redo affected work (corner placement and data collection, or data processing). |
| Geodetic accuracy | Points used for RTK or RTS base stations | Project network must be tied to HARN, CORS, OPUS or other recognized network[r]. Project control points that are used more than once must be repeatable to within 5 cm. | For points used more than once, repeat occupation[s] of each point used, either monthly (for frequently used points) or before re-use (if used infrequently[t]). | Reset points not located at original locations or resurvey point following approved UFP-QAPP |
| Geodetic repeatability* | Grid centroids or corners/transect points without anomaly reacquisition[u] | Measured locations are reoccupied within 10 m.[v] | 1 per lot | Lot submittal fails. |

Note: Performance metrics marked with an * are default values that may be changed by the PDT to suit project needs, potentially as a result of TPP decisions.

[a] These are the critical requirements for RI DGM methods. Contractors shall use additional methods/frequencies that they deem beneficial and as required in their SOPs.

[b] All failures also require a root-cause analysis.

[c] Item should be placed on a jig that ensures consistent geometry between the sensor and item to ensure repeatability, response not to exceed 500 units, or optionally use the Geonics calibration coil. Duration of data collection needed to be determined by the contractor. Must compare to original to ensure instrument is consistent throughout the project. It is recognized that this QC requirement may be redundant and could contradict results from seeding QC; however, in the event of seed failure, information from this test may aid in determining cause of failure (i.e., instrument or processing).

[d] 25 cm based on institutional knowledge and common instrument physical dimensions. Assumes speed used achieves detection. This requirement can be relaxed if supporting documentation is provided to the government for concurrence.

[e] Needed because increase in speed can reduce SNR and increase number of false hits (alternatively, this test can be supplanted by repeatable anomaly characteristics of seed items within the dataset).

[f] Recommended default line spacing is 0.6 m for items of interest the size of 40 mm grenades and smaller, otherwise, 0.8 m.

[g] The terms grid and dataset refer to logical groupings of data or data collection event. Logical groupings of data are contiguous areas mapped by the same instrument and in the same relative timeframe. These can be grids, acres, or some other unit of area. A data collection event is similar to logical groupings of data but refers to data collected over a contiguous timeframe, such as morning, afternoon, battery life, or some other measure of contiguous time. It is recognized that physical marking of corners on the ground is not always beneficial to the government. Additionally, size and shape of the grid is not specified.

[h] It is recommended that IVS seeds items not be buried to a depth where the minimum IVS response is less than approximately 25 mV. Burial at depths that result in small responses (e.g., 5-15 mV) may result in failure to meet the performance standard due to relatively small variations in response that are part of the error budget (e.g., response variations due to sensor bounce).

[i] The expected response is the site-specific value determined in initial IVS testing through averaging several runs of the IVS.

[j] Site-specific DQOs may necessitate smaller positioning repeatability requirements or may allow the requirements to be relaxed . Smaller positioning repeatability may be required for advanced classification methods and for sites with smaller TOIs (e.g., 37mm projectiles). The requirement may be relaxed for sites with only larger TOI (e.g., 100-lb bombs), or other site-specific reasons.

[k] Resolved is defined as 1) there is no geophysical signal remaining at the flagged/selected location; 2) a signal remains but it is too low or too small to be associated with TOI; 3) a signal remains but is associated with surface material which when moved results in low, or no, signal at the interpreted location; or 4) a signal remains and a complete rationale for its presence exists.

[l] Mapping shall cover the required number of anomaly locations. This is used in lieu of checking individual anomalies for those instances where it is quicker to remap sections of land rather than return to individual anomalies. Only the data at the anomaly locations are reviewed for resolution.

[m] This may require leaving flags at excavated locations until QC is complete. It is up to the contractor to indicate which holes knowingly have metal left in them where the PDT has agreed such is acceptable. It is the contractor's responsibility to not put hot material back in the hole before QC is complete. As part of this requirement, location accuracy also must be demonstrated (i.e., cleared location is within dynamic positioning error radius as described above). Contractor SOPs that incorporate post-excavation inspections using digital geophysical instruments can be used to meet the excavation verification need of this requirement provided appropriate QC protocols in place to monitor and document the SOPs are followed. Acceptance sampling or alternative QC protocols to monitor and document the reacquisition SOP would be required to demonstrate the correct locations are excavated.

[n] This is a statistical test number. These values have been used successfully on previous projects. The PDT may choose to modify the statistical confidence level or the number of unresolved anomalies that are allowable on a site-specific basis. The statistical test number does not imply there are 5% bad units. It tests that there are fewer than 5% bad units, including zero bad units. The PDT determines values for confidence levels, which are dependent on the information needed. Stopping rules take precedence over this standard (e.g., for high MEC density, decision could be made to stop because the team has enough data for characterization).

o Contractor shall propose the lot size and criteria for designation (i.e., woods vs. open).

[p] For example, if lot size is 500 anomalies, to achieve a 90% confidence that there are less than 5% unresolved anomalies, 43 anomalies must be rechecked. If any one of the 43 is unresolved, then the confidence level has not been met, the lot submittal fails, and all anomalies in that lot must be rechecked (i.e., accept on zero). The contractor shall propose the lot size for government concurrence. (The contractor determines the amount of risk they are willing to take. The larger the lot, the less sampling needs to be done, but the larger the risk of increased costs/rework if failure occurs.) For anomaly resolution, in order to use statistics/confidence levels, it is based on number of anomalies not grids.

[q] Most high-accuracy systems should demonstrate repeatability between 5 cm and 10 cm. Typical accuracies achievable for some high-accuracy systems are 2 cm to subcentimeter for RTK DGPS and RTS units depending on manufacturer and site conditions. Less accurate systems should demonstrate repeatability within manufacturer published ranges. Typical accuracies for less accurate systems are 5 m to submeter for WAAS or satellite correction service DGPS units, depending on manufacturer, correction service, and site conditions; and 30 m to 1 m for U.S. Coast Guard beacon corrected units, depending on manufacturer and distance from beacon.

[r] The plan for tying the project network to a common reference network must be described in the approved UFP-QAPP. If monumentation is part of the plan, specific monumentation procedures and DQOs also need to be specified, and installation of monumentation or network control points shall follow all guidance and accuracies specified in EC 1110-1-73 “Standards and Specifications for Surveys, Maps, Engineering Drawings, and Related Spatial Data Products.”

[s] Repeat occupation means demonstrate the control points being used can be recovered and reoccupied and that they have not moved more than the requirement specification. This can be accomplished using the same methodology used to initially tie the local network to a HARN, CORS, OPUS, or other recognized network, or it can be accomplished by other means that achieve this requirement.

[t] An example of frequently used control points would be points used as RTK DGPS base stations. Infrequently used points could be those used during RTS operations where the control point was used during mapping and then again at some later time for reacquisition and QC statistical sampling. Infrequently used points also could include grid corners; they are used for line and fiducial positioning and then reused for reacquisition or QC statistical sampling.

[u] Geodetic repeatability metric referenced here is the accuracy required for the grid corners or transect endpoints required to place the grid or transect locations on project site map. This test is not the accuracy requirements for DGM target location and reacquisition.

[v] The exact location of a single transect/grid is not critical when the information is used only for characterization by interpolating over large areas (e.g., transect spacings are larger than geodetic accuracies). The PDT may tighten the acceptable accuracy if more exact positioning is needed (e.g., trying to characterize extents of small MRSs). If specific anomalies/locations must be recovered, this metric must be revised to meet project needs and likely will have the same accuracy needs as the geodetic accuracy requirement.

Table 11-4: Performance Requirements for RI/FS Using Analog Methods[a]

| Requirement | Limited Applicability (Specific to Collection Method/Use) | Performance Standard | Frequency | Consequence of Failure[b] |
|---|---|---|---|---|
| Repeatability (instrument functionality) | All | All items in test strip detected (trains ear daily to items of interest)[c] | Min 1 daily[d] | Remedial training and additional remedial measures as described in the approved UFP-QAPP if due to operator error, or replacement of faulty equipment.[e] |
| Dynamic repeatability | Transects used only for density estimates | Repeat a segment of transect and show number of counts repeated within the greater of ±20% or ±8, or within range of adjacent segments. | Second party repeat of 2% per lot | Redo lot |
| | Transects with digging | Repeat a segment of transect and show extra flags/digs not greater than the greater of 20% or 8 flags/digs, or within range of adjacent segments. | Second party repeat of 2% per lot | Redo lot |
| Coverage, detection and recovery* | Grids | 95% of blind coverage seeds and blind detection seeds are recovered[f]: | Per operator per lot[g]: variable 1–2 large/deep and 1–3 small/ shallow[h]. | Redo lot |
| Anomaly resolution*[i] | Verification checking of excavated locations (analog or digital instrument)[j] | Second party checks open holes to determine:<br>90% confidence < 5% anomalies unresolved[k]<br>Accept on zero.[l] | Rate varies depending on lot size[g]. See Table 6-6: Acceptance Sampling Table for Anomaly Resolution[m]. | Redo lot |
| | Verification checking by DGM remapping[n] | 90% confidence <5% unresolved anomalies[k]<br><br>Accept on zero.[l] | Rate varies depending on lot size[g]. See Table 6-6: Acceptance Sampling Table for Anomaly Resolution.[m] | Redo lot |

| Requirement | Limited Applicability (Specific to Collection Method/Use) | Performance Standard | Frequency | Consequence of Failure[b] |
|---|---|---|---|---|
| Geodetic equipment functionality * | All | Position offset of known/temporary control point within expected range as described in the approved UFP-QAPP.[o] | Daily | Redo affected work |
| Geodetic accuracy | Points used for RTK or RTS base stations | Project network must be tied to HARN, CORS, OPUS or other recognized network[p]. Project control points that are used more than once must be repeatable to within 5 cm. | For points used more than once, repeat occupation[q] of each point used, either monthly (for frequently used points) or before reuse (if used infrequently)[r]. | Reset points not located at original locations or resurvey point following approved UFP-QAPP. |
| Geodetic repeatability * | Grid corners/transect points without anomaly reacquisition | Measured locations are reoccupied within 10 m.[s] | 1 per lot | Redo affected work |

Note: Performance metrics marked with an * are default values that may be changed by the PDT to suit project needs, potentially as a result of TPP decisions.

[a] These are the critical requirements for RI analog methods. Contractors shall use additional methods/frequencies that they deem beneficial and as required in their SOPs.

[b] All failures also require a root-cause analysis.

[c] The requirement is that each operator demonstrates positive detection on a daily basis of the smallest and largest expected MEC of interest when placed at both their best and worst orientations and buried between 95% and 100% of their respective maximum consistent detection depth.

[d] Random blind reconfiguration of test strip also is required (i.e., moving/adding items) at a frequency determined by the contractor and approved in the UFP-QAPP, to address the potential for simply memorizing seed locations.

[e] Some examples of additional remedial measures are removal of operator from mapping for 1 day, retesting on new blind strip meeting the same requirements for seed items (could move location of items in same area), 100% QC reinspection of initial lanes by that operator, etc.

[f] Coverage seeds are small pieces of metal that will produce relatively large amplitude anomalies over small areas, such as small washers or ball bearings. Known location accuracy of placement is not critical. See table note g for description of blind detection seeds.

[g] Contractor shall propose the lot size and criteria for designation (i.e., woods vs. open).

[h] Detection and recovery must be demonstrated consistently for the hard to detect items; therefore, seed items (e.g., ISOs) that are representative of the largest expected MEC and the smallest expected MEC shall be placed between 95% and 100% of their respective maximum consistent detection depth.

[i] Resolved is defined as 1) there is no geophysical signal remaining at the flagged/selected location, or 2) a signal remains but it is too low or too small to be associated with TOI, or 3) a signal remains but is associated with surface material which when moved results in low, or no signal at the interpreted location, or 4) a signal remains and a complete rationale for its presence exists.

[j] This requires leaving flags at excavated locations until QC is complete. If shovel called to a flag during QC then the failure has already occurred—it is not important that something large or small comes out of the hole. Assumption here is mapping coverage is addressed through other means. It is up to the contractor to indicate which holes knowingly have metal left in them where the PDT has agreed such is acceptable. It is the contractor's responsibility to not put hot material back in the hole before QC is complete.

[k] This is a statistical test number. These values have been used successfully on previous projects. The PDT may choose to modify the statistical confidence level or the number of unresolved anomalies that are allowable on a site-specific basis. The statistical test number does not imply there are 5% bad units. It tests there are fewer than 5% bad units, including zero bad units. Values for confidence levels will be determined by the PDT and are dependent on the information needed. Stopping rules will take precedence over this standard (i.e., for high MEC density, decision could be made to stop because the team has enough data for characterization).

[l] Unresolved anomaly means a significant signal remains without a complete rationale for its presence.

[m] For example, if lot size is 500, to achieve a 90% confidence that there are less than 5% unresolved anomalies, 43 anomalies must be rechecked. If any one of the 43 is unresolved, then the confidence level has not been met, the lot submittal fails, and all anomalies in that lot must be rechecked (i.e., accept on zero). The contractor shall propose the lot size for government concurrence (i.e., The contractor determines the amount of risk they are willing to take. The larger the lot, the less sampling needs to be done, but the larger the risk of increased costs/rework if failure occurs.). For anomaly resolution, in order to use statistics/confidence levels, it is based on number of anomalies not grids.

[n] Mapping shall cover the required number of anomaly locations. This is used in lieu of checking individual anomalies for those instances where it is quicker to remap sections of land rather than return to individual anomalies. Only the data at the anomaly locations are reviewed for resolution.

[o] Most high-accuracy systems should demonstrate repeatability between 5 cm and 10 cm. Typical accuracies achievable for some high-accuracy systems are 2 cm to subcentimeter for RTK DGPS and RTS units, depending on manufacturer and site conditions. Less accurate systems should demonstrate repeatability within manufacturer published ranges. Typical accuracies for less accurate systems are 5 m to submeter for WAAS or satellite correction service DGPS units depending on manufacturer, correction service and site conditions, and 30 m to 1 m for U.S. Coast Guard beacon corrected units, depending on manufacturer.

[p] The plan for tying the project network to a common reference network must be described in the approved UFP-QAPP. If monumentation is part of the plan, specific monumentation procedures and DQOs also need to be specified and installation of monumentation or network control points shall follow all guidance and accuracies specified in EC 1110-1-73, "Standards and Specifications for Surveys, Maps, Engineering Drawings, and Related Spatial Data Products."

[q] Repeat occupation means demonstrate the control points being used can be recovered and reoccupied and that they have not moved more than the requirement specification. This can be accomplished using the same methodology used to initially tie the local network to a HARN, CORS, OPUS, or other recognized network, or it can be accomplished by other means that achieve this requirement.

[r] An example of frequently used control points would be points used as RTK DGPS base stations. Infrequently used points could be those used during RTS operations where the control point was used during mapping and then again at some later time for reacquisition and QC statistical sampling. Infrequently used points could also include grid corners they are used for line and fiducial positioning and then subsequently re-used for reacquisition or QC statistical sampling.

[s] The exact location of a single transect/grid is not critical when the information is used only for characterization by interpolating over large areas (e.g., transect spacings are larger than geodetic accuracies). The PDT may tighten the acceptable accuracy if more exact positioning is needed (e.g., trying to characterize extents of small MRSs). If specific locations must be recovered this metric must be revised to meet project needs and likely will have the same accuracy needs as the Geodetic Accuracy requirement, which is 30 cm.

Table 11-5: Performance Requirements for RA Using DGM Methods [a]

| Requirement | Applicability (Specific to Collection Method/Use) | Performance Standard | Frequency | Consequence of Failure[b] |
|---|---|---|---|---|
| Static repeatability (instrument functionality)[c] | All | Response (mean static spike minus mean static background) within error budget of predicted response. | Min 1 daily | Day's dataset fails unless seed item is mapped that day with repeatable anomaly characteristics (see dynamic detection repeatability). |
| Along line measurement spacing | All | 98% <= 25cm along line[d] | By dataset | Dataset submittal fails. |
| Coverage * | Data using electronic positioning equipment | >95% coverage at project design line spacing and 98% coverage at 1 meter line spacing.[e] | By grid or dataset[f] | Submittal fails. |
| | Data using fiducial positioning | All blind coverage seeds[g] detected at their emplacement location within the dynamic positioning repeatability metric or lay down guidance ropes & perform random inspection | 4 per system per grid or dataset[f]<br>Or<br>All have range markers (e.g., pin flags, painted ropes) at a maximum distance of 25 ft or ropes for individual lanes, and visual observation minimum once per day | Submittal fails. |
| Dynamic detection repeatability (IVS and GSV blind seeding) | IVS (applies to all) | Peak response repeatable to +/-25% of expected response.[h] | Twice daily. | Submittal fails. |
| | Blind seeds (applies to all) | Peak response >75% of minimum expected response.[h] | 1 per day per team based on expected production rate | Submittal fails. |
| Dynamic positioning repeatability (IVS and GSV blind seeding) | IVS (applies to all) | Position offset of seed item targets < 25cm. | Twice daily. | Submittal fails. |
| | Blind seeds (applies to all) | 90% positioning offset is <=25 cm + ½ line/sensor spacing and 100% is | 1 per day per team based on expected production rate (same | Submittal fails. |

| Requirement | Applicability (Specific to Collection Method/Use) | Performance Standard | Frequency | Consequence of Failure[b] |
|---|---|---|---|---|
| | | <=35cm + ½ line/sensor for digital positioning systems (<=50cm + 1/2 line spacing for fiducially positioned data)<br>OR<br>the positioning DQO required for site specific tasks[i] | item as dynamic detection repeatability) | |
| Target selection | All | All dig list targets are selected according to project design. | By grid or dataset [f] | Submittal fails. |
| Anomaly resolution *[j] | Verification checking by DGM remapping[k] or verification checking with original instrument of anomaly footprint after excavation [l] | 90% confidence < 1% unresolved anomalies[m]<br>Accept on zero | Rate varies depending on lot size.[n] See Table 6-6: Acceptance Sampling Table for Anomaly Resolution.[o] | Lot submittal fails. |
| Geodetic equipment functionality * | All | Position offset of known/temporary control point within expected range as described in the approved UFP-QAPP[p] | Daily | Redo affected work or reprocess affected data. |
| Geodetic internal consistency | Grids with line-and-fiducial positioning | Grid corners are internally consistent within 30 cm on any leg or diagonal. | Per grid | Redo affected work (corner placement and data collection, or data processing). |
| Geodetic accuracy | Points used for RTK or TS base stations | Project network must be tied to HARN, CORS, OPUS or other recognized network.[q] Project control points that are used more than once must be repeatable to within 5 cm | For points used more than once, repeat occupation[r] of each point used, either monthly (for frequently used points) or before re-use (if used infrequently[s]). | Reset points not located at original locations or resurvey point following approved UFP-QAPP. |

Note: Performance metrics marked with an * are default values that may be changed by the PDT to suit project needs, potentially as a result of TPP decisions.

[a] These are the critical requirements for RA DGM methods. Contractors shall use additional methods/frequencies that they deem beneficial and as required in their SOPs.

[b] All failures also require a root-cause analysis.

[c] Item should be placed on a jig that ensures consistent geometry between the sensor and item to ensure repeatability, response not to exceed 500 units, or optionally use the Geonics calibration coil. Duration of data collection needed TBD by the contractor. Must compare to original to ensure instrument is consistent throughout the project. It is recognized that this QC requirement may be redundant and could contradict results from seeding QC; however, in the event of seed failure, information from this test may aid in determining cause of failure (i.e., instrument or processing).

[d] 25 cm based on institutional knowledge and common instrument physical dimensions. Assumes speed used achieves detection. This requirement can be relaxed if supporting documentation is provided to the government for concurrence.

[e] Recommended default line spacing is 0.6 m for items of interest the size of 40 mm grenades and smaller, else 0.8 m.

[f] The terms grid and dataset refer to logical groupings of data or data collection event. Logical groupings of data are contiguous areas mapped by the same instrument and in the same relative timeframe. These can be grids, acres, or some other unit of area. A data collection event is similar to logical groupings of data but refers to data collected over a contiguous timeframe, such as morning, afternoon, battery life, or some other measure of contiguous time. It is recognized that physical marking of corners on the ground is not always beneficial to the government. Additionally, size and shape of the grid are not specified.

[g] Blind coverage seeds are in addition to Dynamic Positioning Repeatability blind seeds and do not need to be ISOs.

[h] The expected response is the site-specific value determined in initial IVS testing through averaging several runs of the IVS.

[i] Site-specific DQOs may necessitate smaller positioning repeatability requirements or may allow the requirements to be relaxed. Smaller positioning repeatability may be required for advanced classification methods and for sites with smaller TOIs (e.g., 37mm projectiles). The requirement may be relaxed for sites with only larger TOI (e.g., 100-lb bombs), or other site-specific reasons.

[j] Resolved is defined as 1) there is no geophysical signal remaining at the flagged/selected location; 2) a signal remains but it is too low or too small to be associated with TOI; 3) a signal remains but is associated with surface material which when moved results in low, or no, signal at the interpreted location; or 4) a signal remains and a complete rationale for its presence exists.

[k] Mapping shall cover the required number of anomaly locations. This is used in lieu of checking individual anomalies for those instances where it is quicker to remap sections of land rather than return to individual anomalies. Only the data at the anomaly locations are reviewed for resolution.

[l] This may require leaving flags at excavated locations until QC is complete. It is up to the contractor to indicate which holes knowingly have metal left in them where the PDT has agreed such is acceptable. It is the contractor's responsibility to not put hot material back in the hole before QC is complete. As part of this requirement, location accuracy also must be demonstrated (i.e., cleared location is within dynamic positioning error radius as described above). Contractor SOPs that incorporate post-excavation inspections using digital geophysical instruments can be used to meet the excavation verification need of this requirement provided appropriate QC protocols are in place to monitor and document the SOPs are followed. Acceptance sampling or alternative QC protocols to monitor and document the reacquisition SOP would be required to demonstrate the correct locations are excavated.

[m] This is a statistical test number. These values have been used successfully on previous projects. The PDT may choose to modify the statistical confidence level or the number of unresolved anomalies that are allowable on a site-specific basis. The statistical test number does not imply there are 1% bad units. It tests that there are fewer than 1% bad units, including zero bad units. The PDT determines values for confidence levels, which are dependent on the information needed. Stopping rules take precedence over this standard (e.g., for high MEC density, decision could be made to stop because the team has enough data for characterization).

[n] Contractor shall propose the lot size and criteria for designation (i.e., woods vs. open).

[o] For example, if lot size is 500 anomalies, to achieve a 90% confidence that there are less than 5% unresolved anomalies, 43 anomalies must be rechecked. If any one of the 43 is unresolved, then the confidence level has not been met, the lot submittal fails and all anomalies in that lot must be rechecked or some other action or actions performed. The contractor shall propose the lot size for government concurrence (i.e., The contractor determines the amount of risk they are willing to take. The larger the lot, the less sampling needs to be done, but the larger the risk of increased costs/rework if failure occurs.) For anomaly resolution, in order to use statistics/confidence levels, numbers of anomalies is used and not numbers of grids.

[p] Most high-accuracy systems should demonstrate repeatability between 5 cm and 10 cm. Typical accuracies achievable for some high-accuracy systems are 2 cm to sub-centimeter for RTK DGPS and RTS units depending on manufacturer and site conditions. Less accurate systems should demonstrate repeatability within manufacturer published

ranges. Typical accuracies for less accurate systems are 5 m to submeter for WAAS or satellite correction service DGPS units depending on manufacturer, correction service and site conditions, and 30 m to 1m for U.S. Coast Guard beacon corrected units depending on manufacturer.

[q] The plan for tying the project network to a common reference network must be described in the approved UFP-QAPP. If monumentation is part of the plan, specific monumentation procedures and DQOs will also need to be specified and installation of monumentation or network control points shall follow all guidance and accuracies specified in EC 1110-1-73, "Standards and Specifications for Surveys, Maps, Engineering Drawings, and Related Spatial Data Products."

[r] Repeat occupation means demonstrate the control points being used can be recovered and reoccupied and that they have not moved more than the requirement specification. This can be accomplished using the same methodology used to initially tie the local network to a HARN, CORS, OPUS, or other recognized network, or it can be accomplished by other means that achieve this requirement.

[s] An example of frequently used control points would be points used as RTK DGPS base stations. Infrequently used points could be those used during RTS operations where the control point was used during mapping and then again at some later time for reacquisition and QC statistical sampling. Infrequently used points could also include grid corners they are used for line and fiducial positioning and then subsequently reused for reacquisition or QC statistical sampling.

Table 11-6: Performance Requirements for RA Using Analog Methods[a]

| Requirement | Limited Applicability (Specific to Collection Method/Use) | Performance Standard | Frequency | Consequence of Failure[b] |
|---|---|---|---|---|
| Repeatability (instrument functionality) | All | All items in test strip detected (trains ear daily to items of interest)[c] | Min 1 daily[d] | Remedial training and additional remedial measures as described in the approved UFP-QAPP if due to operator error, or replacement of faulty equipment.[e] |
| Coverage, detection and recovery * | All | All blind coverage seeds and blind detection seeds recovered[f] | Per operator per lot[g]: variable 1-2 large/deep and 1-3 small/shallow[h] | Redo lot. |
| Anomaly resolution *[i] | Verification checking of excavated locations (analog or digital instrument)[j] | 2nd party checks open holes to determine: 90% confidence < 1%[k] unresolved anomalies.[l] Accept on zero. | Rate varies depending on lot size[g]. See Table 6-6: Acceptance Sampling Table for Anomaly Resolution.[m] | Redo lot. |
| | Verification checking by DGM remapping[n] | 90% confidence < 1%[k] unresolved anomalies.[l] Accept on zero. | Rate varies depending on lot size[g]. See Table 6-6: Acceptance Sampling Table for Anomaly Resolution[m]. | Redo lot. |
| Geodetic equipment functionality * | All | Position offset of known/temporary control point within expected range as described in the approved UFP-QAPP.[o] | Daily | Redo affected work. |

| Requirement | Limited Applicability (Specific to Collection Method/Use) | Performance Standard | Frequency | Consequence of Failure[b] |
|---|---|---|---|---|
| Geodetic accuracy | Points used for RTK or RTS base stations | Project network must be tied to HARN, CORS, OPUS or other recognized network[p]. Project control points that are used more than once must be repeatable to within 5 cm | For points used more than once, repeat occupation[q] of each point used, either monthly (for frequently used points) or before re-use (if used infrequently[r]). | Reset points not located at original locations or resurvey point following approved UFP-QAPP. |

Note: Performance metrics marked with an * are default values that may be changed by the PDT to suit project needs, potentially as a result of TPP decisions.

[a] These are the critical requirements for RA analog methods. Contractors shall use additional methods/frequencies that they deem beneficial and as required in their SOPs.

[b] All failures also require a root-cause analysis.

[c] The requirement is that each operator demonstrates positive detection on a daily basis of the smallest and largest expected MEC of interest when it is placed at both its best and worst orientations and buried between 95% and 100% of their respective maximum consistent detection depth. Maximum consistent detection depth is defined as producing any above background response on a minimum of the first three time gates of the EM61-MK2 optimized for site conditions and having a 0.9 m2 size or more as calculated using the Geosoft Oasis Montaj UCEAnalyseTarget.gx or equivalent routine.

[d] Random blind reconfiguration of test strip is also required (i.e., moving/adding items) at a frequency determined by the contractor and approved in the UFP-QAPP, to address the potential for simply memorizing seed locations.

[e] Some examples of additional remedial measures are removal of operator from mapping for one day, retesting on new blind strip meeting the same requirements for seed items (could move location of items in same area), and 100% QC reinspection of initial lanes by that operator.

[f] Coverage seeds are small pieces of metal that will produce relatively large amplitude anomalies over small areas, such as small nails or ball bearings. Known location accuracy of placement is not critical. See endnote #g for description of blind detection seeds.

[g] Contractor shall propose the lot size and criteria for designation (i.e., woods vs. open).

[h] Detection and recovery must be demonstrated consistently for the hard to detect items; therefore, seed items (e.g., ISOs) that are representative of the largest expected MEC and the smallest expected MEC shall be placed between 95% and 100% of their respective maximum consistent detection depth.

[i] Resolved is defined as 1) there is no geophysical signal remaining at the flagged/selected location, or 2) a signal remains but it is too low or too small to be associated with TOI, or 3) a signal remains but is associated with surface material which when moved results in low, or no signal at the interpreted location, or 4) a signal remains and a complete rationale for its presence exists.

[j] This requires leaving flags at excavated locations until QC is complete. If UXO technicians need to return to a flag during QC, then the failure has already occurred—it is not important that something large or small comes out of the hole. Assumption here is mapping coverage is addressed through other means. It is up to the contractor to indicate which holes knowingly have metal left in them where the PDT has agreed such is acceptable. It is the contractor's responsibility to not put hot material back in the hole before QC is complete.

[k] This is a statistical test number. These values have been used successfully on previous projects. The PDT may choose to modify the statistical confidence level or the number of unresolved anomalies that are allowable on a site-specific basis. The statistical test number does not imply there are 1% bad units. It tests there are fewer than 1% bad units, including zero bad units. Values for confidence levels will be determined by the PDT and are dependent on the information needed. Stopping rules will take precedence over this standard (i.e., for high MEC density, decision could be made to stop because the team has enough data for characterization).

[l] Unresolved anomaly means a significant signal remains without a complete rationale for its presence.

m For example, if lot size is 500, to achieve a 90% confidence that there are less than 5% unresolved anomalies, 43 anomalies must be rechecked. If any one of the 43 is unresolved, then the confidence level has not been met, the lot submittal fails, and all anomalies in that lot must be rechecked (i.e., accept on zero). The contractor shall propose the lot size for government concurrence (i.e., The contractor determines the amount of risk they are willing to take. The larger the lot, the less sampling needs to be done, but the larger the risk of increased costs/rework if failure occurs.). For anomaly resolution, in order to use statistics/confidence levels, it is based on number of anomalies not grids.

[n] Mapping shall cover the required number of anomaly locations. This is used in lieu of checking individual anomalies for those instances where it is quicker to remap sections of land rather than return to individual anomalies. Only the data at the anomaly locations are reviewed for resolution.

[o] Most high-accuracy systems should demonstrate repeatability between 5 cm and 10 cm. Typical accuracies achievable for some high-accuracy systems are 2 cm to sub-centimeter for RTK DGPS and RTS units depending on manufacturer and site conditions. Less accurate systems should demonstrate repeatability within manufacturer published ranges. Typical accuracies for less accurate systems are 5 m to submeter for WAAS or satellite correction service DGPS units depending on manufacturer, correction service and site conditions, and 30 m to 1 m for U.S. Coast Guard beacon corrected units depending on manufacturer.

[p] The plan for tying the project network to a common reference network must be described in the approved UFP-QAPP. If monumentation is part of the plan, specific monumentation procedures and DQOs also need to be specified and installation of monumentation or network control points shall follow all guidance and accuracies specified in EC 1110-1-73 “Standards and Specifications for Surveys, Maps, Engineering Drawings, and Related Spatial Data Products.”

[q] Repeat occupation means demonstrate the control points being used can be recovered and reoccupied and that they have not moved more than the requirement specification. This can be accomplished using the same methodology used to initially tie the local network to a HARN, CORS, OPUS, or other recognized network, or it can be accomplished by other means that achieve this requirement.

[r] An example of frequently used control points would be points used as RTK DGPS base stations. Infrequently used points could be those used during RTS operations where the control point was used during mapping and then again at some later time for reacquisition and QC statistical sampling. Infrequently used points could also include grid corners they are used for line and fiducial positioning and then subsequently reused for reacquisition or QC statistical sampling.

# CHAPTER 12

## Hazard and Risk Assessment

12.1. Introduction.

12.1.1. This chapter describes explosive safety hazard assessment and chemical risk assessment associated with MEC and MC during MR projects. A MEC HA is used to describe baseline explosive safety hazards to human receptors. It also can be used to evaluate relative hazard reductions associated with removal or remedial actions, including LUCs, surface removal, and subsurface removal of MEC. Likewise, an MC risk assessment evaluates the potential threat to human health and the environment from exposure to MC, where the degree of risk is usually proportional to the toxicity of the contaminants as well as the amount and duration of exposure.

12.1.2. An explosives safety hazard is the probability that MEC might detonate and potentially cause harm as a result of human activities. An explosives safety hazard exists if a person can come near or into contact with MEC and then energy of some sort is applied to it to cause it to detonate. The person, external forces not associated with the person's contact, or an internal mechanism within the MEC item itself could apply the energy.

12.1.3. The Army has authorized and encouraged the use of the interim MEC HA as a tool in conducting hazard assessments related to MEC during a trial period. This trial period was scheduled to expire at the end of 2010 but was extended by 2 years. Refer to http://www.epa.gov/fedfac/documents/hazard_assess_wrkgrp.htm, which provides access to an automated MEC HA workbook.

12.1.4. Risks posed by MC are assessed through a process that adheres to the requirements of CERCLA and the NCP. Refer to EM 200-1-4 Volume 1 for HHRA and Volume 2 for ERA and http://www.epa.gov/risk_assessment/guidance.htm.

12.1.5. An MC risk assessment characterizes the nature and magnitude of health risks to humans (e.g., residents, workers, recreational visitors) and ecological receptors (e.g., birds, fish, wildlife) from exposure to MC.

12.2. Conceptual Site Model Development.

12.2.1. The CSM is an ongoing description of a site and its environment that is based on existing knowledge and is updated as the project progresses. It serves as the basis for developing a comprehensive approach for addressing MR actions. It describes sources of MEC and/or MC at a site; actual, potentially complete, or incomplete exposure pathways; current or reasonable proposed use of property; and potential receptors. The CSM serves as a planning instrument, a modeling and data interpretation aid, and a communication device among the PDT to communicate and describe the current state of knowledge and assumptions about the MEC hazard and MC risk at a project property. The CSM evolves as site work progresses and data gaps are filled. See EM 200-1-12, Conceptual Site Models for Environmental and Munitions Projects for additional guidance. This document recommends categorizing information necessary to develop the CSM into five profiles:

a. Facility profile – describes man-made features and potential sources at or near the site

b. Physical profile – describes factors that may affect release, fate and transport, and access

c. Release profile – describes the movement and extent of contaminants in the environment

d. Land use and exposure profile – provides information used to identify and evaluate the applicable exposure scenarios, receptors, and receptor locations

e. Ecological profile – describes the natural habitats of the site and ecological receptors in those areas

12.2.2. A team uses a preliminary CSM as a simple model of the relationships between chemicals and/or MEC and MC potentially located at a site and access to them by site receptors. As more information is gained through data collection, the CSM is refined through the course of the project to reflect site knowledge and uncertainties. For example, the preliminary CSM is useful to identify data gaps to focus site data collection efforts, but a refined CSM in later project stages would document results of an RI and assist in finalizing a remedial strategy and long-term management actions. At the end of the project, the CSM should be updated with the latest information and finalized.

12.3. Munitions and Explosives of Concern Hazard Assessment.

12.3.1. The potential for an explosives safety hazard depends upon the presence of three critical elements to complete the risk pathway. If any one of these three elements is missing, there is no completed pathway and, therefore, no resulting MEC hazard. Each of the three elements also provides a basis for implementing effective hazard management response actions. The three critical elements include:

a. a source of MEC (the presence of MEC at the project site);

b. a receptor or person (the presence of a person at the project site); and

c. the potential for interaction between the source and the receptor (such as the receptor picking up the item or disturbing the item during the implementation of site tasks).

12.3.2. The potential for an explosives safety hazard also depends on the source of MEC. The factors affecting the degree of hazard associated with the MEC source are the quantity and type of MEC. The more MEC present at a project site, the greater the likelihood for an interaction between a receptor and MEC. For example, more MEC are likely to be present at a former target area than at a former function test range. If there are no MEC present, there is no completed pathway and, consequently, no explosives safety hazard.

12.3.2.1. At military training facilities/ranges, it was and is customary to conduct initial training exercises using practice munitions, including on those ranges designated for HE-filled munitions use. Only after troops have demonstrated proficiency in firing tactics are they allowed to use HE-filled munitions. As a result, some training ranges contain a preponderance of practice munitions. Practice munitions also may have tracers, spotting or marking charges associated with them that contain energetic material. Practice munitions that contain these charges present a potential explosive safety hazard.

12.3.2.2. The primary release mechanisms resulting in the occurrence of MEC are related to the type of military munition activity or result from the improper functioning of the military munition. For example, when an HE artillery shell is fired, it will do one of three things:

- It will detonate completely. This is called a high-order detonation.
- It will undergo incomplete detonation. This is called a low-order detonation.
- It will fail to function. This results in UXO.

12.3.2.3. Military munitions may be lost, abandoned, or buried, resulting in unfired munitions that could be fuzed or unfuzed. These are termed DMM.

12.3.2.4. In addition, there are military munitions that will have a delayed function and may be hidden by design resulting in a deployed, armed, and fuzed munition.

12.3.3. Military munitions demilitarization through OB/OD is used to destroy excess, obsolete, or unserviceable munitions by combustion or by detonation. An OD operation can result in high- or low-order detonations. In addition, the munitions possibly may be spread beyond the immediate vicinity from the action of the detonation, which is described as kick-out. Incomplete combustion or low-/high-order detonation failure can leave unconsumed explosives on the project site. Because munitions, including DMM, that remain after being subjected to attempted demilitarization by OB or OD have experienced an abnormal environment according to 6055.09-M, they should be managed as UXO until assessed and determined otherwise by technically qualified personnel.

12.3.4. Receptors are people who potentially may contact MEC items. The factors affecting the hazard associated with the receptor include the number of people that access the area containing MEC and the accessibility and ease of access of the property containing MEC. The more receptors that use the location and the easier it is to access the property, the greater the potential for contact with MEC. The converse is also true: the fewer people that are present and the harder it is to access the property due to man-made (e.g., fences) or natural (e.g., terrain features) barriers, the lower the potential for contact with MEC.

12.3.5. The factors affecting the hazard associated with the interaction with MEC include MEC contact potential, energy application, and MEC sensitivity and potential severity.

12.3.5.1. MEC contact potential is a function of MEC location (surface or subsurface) and the type and frequency of receptor activities that can result in a complete exposure pathway on the surface or in the subsurface. Factors include the depth of the MEC, site stability (frost heave, erosion), and the depth and type of receptor activity. For instance, if the project property is unstable, there is a greater likelihood for subsurface MEC to migrate closer to the surface with increased potential for interaction. Also, for subsurface MEC, as the depth of intrusion by the receptor increases, the likelihood that there will be receptor and MEC interaction may increase.

12.3.5.2. The energy application factor affects the likelihood that a receptor will apply enough energy to a MEC item to cause it to function. The risk to the receptor increases greatly the more energy the receptor applies to a MEC item. Examples are an item is picked up, hit with a hammer, thrown in a fire, etc. However, there also may be the case where the type of MEC requires no force be applied to it by the receptor in order to function. MEC size can, in some cases, influence the ease with which a receptor can apply energy to a MEC item. For example, a very large MEC item (e.g., a large bomb) is not easily picked up, reducing the possibility that a receptor can impart enough energy to cause the item to detonate from dropping.

12.3.5.3. The greater the sensitivity, the greater the likelihood for a MEC item to function. The type of MEC affects the likelihood and severity of injury if a MEC functions. The hazard from MEC typically results from a single interaction between a receptor and a MEC source and may have one of three outcomes: no effect, injury, or death. The consequence of a military munition detonating is associated with physical forces resulting from blast pressure, fragmentation hazards, thermal hazards, and shock hazards. The type of hazard threat and the severity of the hazard depend on the type of MEC and whether or not it is fuzed, for example.

12.3.5.3.1. Different types of military munitions vary in their likelihood of detonation and their potential for harm. The classification of energetic materials used in military munitions can be divided by their primary uses: explosives, propellants, and pyrotechnics. Explosives and propellants, if properly initiated, evolve into large volumes of gas over a short period of time. The key difference between explosives and propellants is the reaction rate. Explosives react rapidly, creating a high-pressure shock wave, and are designed to break apart a munitions casing and cause injury and death. Propellants react at a slower rate, creating a sustained lower pressure. Propellants are designed to provide energy to deliver a munition to its target. Pyrotechnics produce heat but less gas than explosives or propellants. Pyrotechnics are used to send signals, to illuminate areas, to simulate other weapons during training, and as ignition elements for certain weapons. When initiated, pyrotechnics produce heat, noise, smoke, light, or infrared radiation. Incendiaries are a class of pyrotechnics that are highly flammable and are used to destroy a target by fire.

12.3.5.3.2. Practice rounds contain an energetic (low explosive or pyrotechnic charge) and include a fully functional fuzing system, while training rounds are wholly inert. A practice round can, in some cases, pose a similar level of hazard to an HE-filled UXO item. The hazard from a practice round may result from a fuze or spotting charge contained in the munition in order to produce a flash or smoke upon impact. Unexpended spotting charges may cause a flesh burn. Wholly inert training rounds have no explosive parts, including fuze components, and do not pose an explosive safety hazard.

12.3.6. The MEC HA is used to assess the hazards associated with MEC at land-based MRSs and complements the MRSPP (see Section 13.4). It is a qualitative tool with relative scoring values, with emphasis on EE/CA and RI/FS evaluations and analyses to support site-specific remedy selections. MEC HA does not set DQOs or replace HHRAs and ERAs for MC, nor is it used to make a cleanup decision. It utilizes inputs based on severity, accessibility, and sensitivity components.

a. Severity component: Input factors include energetic material type and location of additional human receptors.

b. Accessibility component: Input factors include site accessibility, potential contact hours, amount of MEC, minimum MEC depth relative to maximum receptor intrusive depth, and migration potential.

c. Sensitivity component: Input factors include MEC classification and MEC size.

12.3.6.1. Each input factor has a maximum score and weighting, with the input factors associated with the accessibility component carrying the highest combined weight compared to the other two factors.

12.3.6.2. Each input factor has two or more categories that determine the score assigned to that input factor. These categories describe all reasonable MRS conditions, including the MRS at a baseline condition, the MRS after a surface cleanup, and the MRS after a subsurface cleanup. This approach allows an MRS to be assessed with different remedial or removal alternatives, including LUCs. For example, the energetic material type factor for the severity component assigns relative scores for each of the three MRS conditions, including the highest score of 100 for "high explosives and low explosive filler in fragmenting rounds" and the lowest score of 30 to "incendiary."

12.3.6.3. The MEC HA scoring of an MRS results in one of the following hazard levels being assigned to each remedial or removal alternative, which provides a way of evaluating the relative MEC hazard potential reductions provided by each alternative relative to the baseline (current) conditions at the MRS.

- Hazard Level 1: Sites with the highest hazard potential
- Hazard Level 2: Sites with a high hazard potential
- Hazard Level 3: Sites with a moderate hazard potential
- Hazard Level 4: Sites with a low hazard potential

12.3.6.4. See http://www.epa.gov/fedfac/documents/hazard_assess_wrkgrp.htm for complete information about the application and use of the MEC HA tool.

12.4. Munitions Constituents Risk Assessment.

12.4.1. HHRA.

12.4.1.1. The HHRA evaluates the potential for adverse human health effects occurring that are attributable to site contamination, including contamination by MC. The CSM, which is revised as appropriate based on additional information about a site, is used to focus the HHRA. Screening-level HHRAs are performed at sites during the PA/SI stage to determine whether a site needs to be assessed further or can be eliminated from further concern. The conservative evaluation is based on comparing MC contamination levels with health-based screening levels. Baseline HHRAs are performed at sites during the RI/FS stage. This section focuses on the baseline HHRAs.

12.4.1.2. The process for characterizing risks to human health from exposure to MC is conducted in five phases during the baseline HHRA:

a. Selecting MC COPCs

b. Exposure assessment

c. Toxicity assessment

d. Risk characterization

e. Evaluation of uncertainties and limitations

12.4.1.2.1. Methodology. The methodology was largely developed from the USEPA's RAGS (http://www.epa.gov/oswer/riskassessment/ragsa/index.htm). Refer also to USACE's guidance for performing HHRAs (Volume 1 of EM 200-1-4). Additionally, USEPA regional and state regulatory guidance should be used as required and deemed appropriate.

12.4.1.2.2. Selecting COPCs. COPCs should be identified that represent chemicals detected at a site that could pose a potential health risk to exposed human receptors. The selection process is based on evaluation of useable site data using a number of criteria designed to screen out chemicals that are not appropriate to retain as COPCs. Key factors include determining the exposure area(s) and assessing the appropriateness of the site data. Chapter 7 provides information about the MC associated with different types of munitions. These MC should be considered when selecting COPCs during this phase, depending on the type or range, the munitions used, and the associated activities that have taken place. EM 200-1-4 Volume I provides guidance on the general considerations for selecting COPCs and specific COPC selection criteria. The conclusion of the chemical selection process is a subgroup of MC that are selected as COPCs, which are evaluated further in the baseline HHRA. Tables should be developed segregating the COPCs selected for each medium and/or exposure area. All MC that were removed from consideration should be identified, with an explanation of the reason for their exclusion.

12.4.1.2.3. Exposure Assessment. During the BRA, the exposure assessment estimates the nature, extent, and magnitude of potential exposure of human receptors to the COPCs that are present or migrating from the site, considering both current and plausible future use of the site. Several steps are required during this assessment, including:

- characterizing the exposure setting (identifying the physical features of the site that may influence the exposures based on current use and those that may influence exposures based on reasonably anticipated future use);

- identifying potential exposure pathways and exposure routes (with complete exposure pathways consisting of a source and mechanism of chemical release, an intermedia transport mechanism, a migration pathway, a receptor group who may come into contact with the chemical, and an exposure route through which chemical uptake by the receptor occurs [e.g., ingestion of soil]);

- identifying potentially exposed receptor populations (based on current and anticipated future use of the site, and current and future activities of receptors on or near the site); and

- quantifying exposure (i.e., intake or dose) that could occur for complete exposure pathways for each receptor group, with respect to the magnitude, frequency, and duration of exposure.

12.4.1.2.3.1. Consideration should be given to the spatial relationships of pathways and the need to segregate the site into smaller exposure units to properly evaluate risks to some receptor groups. The estimation of EPC (i.e., the chemical concentrations the receptor potentially will contact during the exposure period), whether from fate and transport modeling and/or site data, is a key component of the exposure assessment. Depending on the operational history of the site, the investigative approach, the available data, and the chemical, a number of EPCs (e.g., 95% upper confidence limit on the mean concentration, mean concentration, maximum concentration) could be used.

12.4.1.2.3.2. EM 200-1-4 Volume I provides guidance on fate and transport modeling. Consideration should be given to estimating a range of potential exposures (e.g., reasonable maximum exposure scenario, average exposure scenario). At the conclusion of the exposure assessment, the uncertainties associated with chemical intake should be summarized.

12.4.1.2.4. <u>Toxicity Assessment</u>. The toxicity assessment results in the selection of the toxicity values that will be used to estimate the potential human health risks associated with exposure to the MC COPCs and forms the basis for developing summaries of the potential toxicity of the MC COPCs for inclusion in the risk assessment. This is an area of intense ongoing research and study for MC. Examples include toxicity of PAHs contained in the binder used for clay pigeon targets and the toxicity of lead. The USEPA is updating and expanding relative cancer potency factors for various PAHs using benzo(a)pyrene as a reference, which may impact toxicity assessment for these chemicals in the future. The USEPA and other jurisdictions are contemplating lowering the threshold for assessing exposure to lead, by factors of 2 or 10 or more. In addition, toxicity evaluations for energetic (e.g., technical grade DNT) and chemical agents and their breakdown products may result in changes that affect future toxicity assessments. A three-tier hierarchy of toxicity values must be used when selecting values for risk assessment purposes (see DoDI 4715.18 for more information):

- USEPA Integrated Risk Information System database (http://www.epa.gov/iris/index.html)

- USEPA PPRTV for Superfund database (http://hhpprtv.ornl.gov/index.shtml)

- Other toxicity values. EM 200-1-4 Volume I provides guidance on additional sources of toxicity information. This includes additional USEPA and non-USEPA sources of toxicity information. Priority should be given to sources of information that use sound science and are the most current, peer-reviewed, transparent, and publicly available. Example sources include the California Environmental Protection Agency, Office of Environmental Health Hazard Assessment Toxicity Criteria Database (http://www.oehha.ca.gov/risk/chemicalDB/index.asp), and the U.S. Department of Human and Health Services, ATSDR Minimal Risk Levels (http://www.atsdr.cdc.gov/mrls/index.asp).

12.4.1.2.5. Risk Characterization. In the risk characterization, the chemical intakes estimated in the exposure assessment are combined with the appropriate critical toxicity values identified in the toxicity assessment. The results are the estimated incremental lifetime cancer risks and noncarcinogenic health hazards posed by the exposures. Along with the numerical estimates of potential health risks and hazards, a narrative describing the primary contributors to health risks and hazards and factors qualifying the results is presented. EM 200-1-4 Volume I provides information on methods for characterizing the risk associated with carcinogenic and noncarcinogenic chemicals.

12.4.1.2.6. Uncertainty and Limitations Analysis. The risk assessment must include an objective and candid analysis of the uncertainties and limitations associated with the description of risks and associated conclusions. This provides the decision maker with a better understanding of the implications and limitations of the risk assessment. Sources of uncertainty may be related to variability in sampling and analysis of MC at the site (see Chapters 7 and 8) and in estimating the exposure to human receptors and from data gaps (e.g., using approximations for fate and transport, exposures, intakes, and toxicity). EM 200-1-4 Volume I provides guidance for preparing the uncertainty analysis.

12.4.2. ERA.

12.4.2.1. Purpose. The purpose of an ERA is to evaluate whether potential adverse ecological effects are occurring or could occur from stressors in the environment, with the focus on contamination by MC. The process for characterizing the potential for adverse effects during an ERA is generally conducted in four phases (problem formulation, ecological effects characterization, exposure characterization, and risk characterization) and follows the process described in the USEPA's Ecological Risk Assessment Guidance for Superfund (ERAGS) (http://www.epa.gov/oswer/riskassessment/ecorisk/ecorisk.htm). Refer also to USACE's guidance for performing ecological risk assessments (Volume II of EM 200-1-4). This process generally is followed for both SLERA and BERA.

12.4.2.2. SLERA. Steps 1 and 2 of ERAGS are implemented through a SLERA, which includes screening-level problem formulation, effects evaluation, exposure estimation, and risk calculation (Refer to A Guide to Screening Level Ecological Risk Assessment at http://aec.army.mil/usaec/cleanup/ecorisk03-0405.pdf). During the screening-level problem formulation, an initial CSM is developed, which includes evaluation of the environmental setting, chemical fate and transport mechanisms, mechanisms of ecotoxicity, and complete exposure pathways. Assessment endpoints are considered any adverse effects on ecological receptors where exposure pathways are complete. The screening-level effects evaluation identifies conservative thresholds of ecotoxicity or screening ecotoxicity values protective of the ecological receptors being evaluated. Next, exposures are estimated under the conservative assumptions that chemicals are 100% bioavailable, 100% of an ecological receptor's diet is contaminated, and the home range of all ecological receptors is within the contaminated area. Lastly, a screening-level risk calculation incorporates the estimated exposures with the screening ecotoxicity values into a quantitative estimate of the potential for adverse effects. The hazard quotient method (the ratio of the estimated exposure or medium exposure concentration to the screening ecotoxicity value) is used in the screening-level risk calculation.

12.4.2.2.1. The SLERA results in a scientific/management decision point where:

- there is adequate information to conclude that the risks are negligible and NFA is required;

- the information is not adequate to conclude NFA and a BERA is required; and

- the information points to the potential for adverse effects and a more thorough assessment is warranted.

12.4.2.2.2. When information is not adequate to conclude NFA and it seems a BERA may be required, it may be worthwhile to refine some exposure parameters from the SLERA with more realistic parameters if it is likely that reasonable / more realistic exposure parameters would help resolve the question of risk. The parameters that should be considered for refinement are discussed in A Guide to Screening Level Ecological Risk Assessment (http://aec.army.mil/usaec/cleanup/ecorisk03-0405.pdf). The results of the refinement are used to determine whether or not the potential for adverse ecological risk is negligible such that an appropriate risk management decision may be made or great enough to warrant a BERA.

12.4.2.3. BERA. The BERA is implemented as steps 3 through 8 of ERAGS. Step 3 of ERAGS includes refinement of the problem formulation and identification of appropriate assessment endpoints. In the BERA problem formulation, additional site-specific information is used to refine the CSM, which helps define the scope and goals of the BERA. Steps 4, 5, and 6 of ERAGs involve the planning and execution of a study designed to answer questions or test hypotheses concerning the potential for adverse effects on the assessment endpoints. Measurement endpoints (i.e., measurable ecological characteristics which are related to the values characteristic chosen as the assessment endpoint) are selected during this process.

12.4.2.3.1. The BERA focuses on a lines-of-evidence approach for demonstrating adverse effects at the population and community levels and uses a reference area for comparison. Lines of evidence evaluated during the BERA may include:

- comparison of estimate or measure ingested doses with toxicity reference values;

- comparison of on-site tissue residues with those from a reference area;

- comparison of on-site toxicity test results with those from a reference area;
- comparison of observed effects on-site receptors with those from a reference area; and
- comparison of measures of population or community health with those from a reference area.

12.4.2.3.2. Risk Characterization. Risk characterization involves risk estimation and risk description steps. Exposure and effects estimates are integrated into statements about the potential for adverse effects on assessment endpoints. Adverse effects are undesirable changes that alter valued structural or functional attributes of the ecological entities under consideration. The risk description includes a summary of ecological risk and an interpretation of ecological significance. Uncertainties and assumptions used in characterizing the potential for adverse effects posed by the MC are documented.

12.4.2.4. Resources for Conducting ERAs. In addition to the sources cited above, Table 12-1 provides references to tools for conducting ERAs and for data on toxicity values for various MC classes.

Table 12-1: ERA Technical Resources

| |
|---|
| Tools for Conducting BERAs<br>• Adaptive Risk Assessment Modeling System (http://el.erdc.usace.army.mil/arams)<br>• Terrestrial Wildlife Exposure Model (http://phc.amedd.army.mil/topics/labsciences/tox/Pages/ARAMS.aspx)<br>• Spatially Explicit Exposure Model and Habitat Suitability Database (http://phc.amedd.army.mil/topics/labsciences/tox/Pages/ARAMS.aspx) |
| Toxicity (Energetics)<br>• USAPHC Wildlife Toxicity Assessments (http://phc.amedd.army.mil/topics/labsciences/tox/Pages/WTA.aspx)<br>• USAPHC Terrestrial Toxicity Database (http://phc.amedd.army.mil/topics/labsciences/tox/Pages/ARAMS.aspx)<br>• Risk Assessment Information System (RAIS) Ecological Benchmark Tool (http://rais.ornl.gov/tools/eco_search.php) |
| Toxicity (Metals and Other MC)<br>• USEPA Ecological Soil Screening Levels (http://www.epa.gov/ecotox/ecossl/)<br>• RAIS Ecological Benchmark Tool (http://rais.ornl.gov/tools/eco_search.php)<br>• USEPA Ambient Water Quality Criteria (http://www.epa.gov/waterscience/criteria/wqcriteria.html) |

12.4.3. Underwater MRSs.

12.4.3.1. Risk assessment at underwater MRSs presents unique challenges because of environmental issues and the relative newness of the state of the science compared to land-based ranges (Refer to Munitions in the Underwater Environment: State of the Science and Knowledge Gaps; SERDP/ ESTCP White Paper -- http://www.serdp.org/Featured-Initiatives/Munitions-Response-Initiatives/Munitions-in-the-Underwater-Environment). The Marine Technology Society recently has published several papers in their journal related to munitions in the underwater environment, including Legacy Underwater Munitions: Assessment, Evaluation of Impacts, and Potential Response Technologies and The Legacy of Underwater Munitions Worldwide: Policy and the Science of Assessment, Impacts and Potential Responses (https://www.mtsociety.org/publications/).

12.4.3.2. Underwater Munitions Sites. Munitions are found in all types of water environments, including in the ocean, both near shore and off shore, and in lakes, rivers, and swamps. These environments are complex and have varying characteristics, such as water/sediment depth, temperature, salinity, bathymetry, and sediment type, and are subject to a variety of water chemistries from oxidative to reductive in nature. Munitions types may include bombs, projectiles, mortars, grenades, and rockets and may lie on the surface of sediment, buried, or intact (e.g., UXO) or partially intact (e.g., low-order detonation).

12.4.3.3. MC Release. Estimating the amount of MC released to the environment from individual munitions and all munitions at a site over time is a critical component of the CSM. The fate and transport of MC depends on several factors, including ambient current speed (if any), breach hole size, volume of cavity, dissolution rate of MC, and the hydrodynamic mixing coefficient. Recent research on models such as that undertaken through ESTCP may help in estimating munitions mobility and burial in the underwater environment (e.g., UXO Mobility Model). Mobility information can be used to support a risk assessment by identifying the areas and entombment depths likely to contain munitions, thus reducing costs associated with fieldwork.

12.4.3.3.1. The release of MC from intact underwater munitions depends largely on the rate of corrosion. Understanding the condition of munitions casings helps to characterize the potential for energetic fill material to move into the environment. The UXO Corrosion Prediction Model developed under the Navy's Environmental Sustainability Development to Integration Program addresses corrosion in the underwater environment. SERDP is undertaking research to develop a scientific basis for quantitatively estimating the source terms associated with breached or broken projectile casings along with the fate and transport of MC contamination in the aquatic environment.

12.4.3.3.2. ERDC and others have investigated the ecotoxicity of TNT, RDX, and HMX, along with their uptake, biotransformation, and elimination in fish mollusks and various other underwater marine life and is assessing the toxicity of explosives in sediments. Refer to the Munitions in the Underwater Environment: State of the Science and Knowledge Gaps; SERDP/ESTCP White Paper cited above for more information.

12.5. Hazard and Risk Management Principles.

12.5.1. Risk management consists of a two-part response: those MR actions that remove the hazard, such as physical removals, and those MR actions that manage the residual hazards, such as LUCs.

12.5.1.1. Physical Removal. Physical removal involves reducing the quantity of MEC and associated MC at the property, which reduces the likelihood that contact with MEC or MC will occur. However, there frequently is residual hazard at MRSs since it is either technically or financially impracticable to provide 100% removal of all MEC items or technically or financially impractical to prove 100% of the MEC have been removed.

12.5.1.1.1. For example, where MEC depth exceeds the detection depth limitations of detection technology, a decision may be made to accept and manage the residual hazard. Alternatively, if the residual hazard in such cases is unacceptable, the PDT may decide to take steps to clear to the detection depth, remove soil from the cleared area, and resume detection and clearance activities in that same area until the desired level of residual risk is reached based on current and future land use considerations.

12.5.1.1.2. Advanced EMI sensors allow for a greater level of classification of detected anomalies as either TOIs or non-TOIs. This allows the PDT additional flexibility during RAs and removal actions to leave anomalies in place that have been classified as nonhazardous using these sensors. Although there is the possibility that TOIs may be misclassified as non-TOIs, the residual risk is not different from leaving behind TOIs due to an analog process failure or limitations on the capability of analog or DGM systems. If a TOI is misclassified as non-TOI, it is likely that the MEC will not be included on the dig list and, therefore, will remain at the site after the investigation. The PDT must implement QC methods and procedures to help ensure the efficacy of the classification system so that the residual hazard is understood and adequately managed. Chapter 6 provides information on the advanced EMI sensors and associated procedures for their use, while Chapter 11 discusses the QC considerations for classification.

12.5.1.2. LUCs. LUCs can be used to effectively manage the residual risk and are an important component of the overall risk management strategy. LUCs may consist of educational awareness programs, legal restrictions on land use, and physical access controls. See EP 200-1-20 for procedural information on establishing and maintaining LUCs. The educational awareness program should be the cornerstone of the LUC program because of the paramount importance of effective risk communication. Controlling or altering the behavior of receptors can reduce the potential for interaction with MEC and MC and reduce the risks and hazards. Defense Environmental Network & Information Exchange provides an Internet Web-based Educational Program, available at http://www.denix.osd.mil/uxo/. LUCs, such as access and activity restrictions, also can be used to decrease the number of receptors and the potential for interaction with MEC and MC. If you reduce the number of receptors on site and the activities that cause interaction, the likelihood of interaction of MEC and MC is reduced. LUCs can only be part of a successful remedy if they are effectively implemented and maintained. A comprehensive LUC program should include periodic reviews (generally annually) for assuring the continued effectiveness of the program.

12.5.1.3. Safety. The U.S. Army Technical Center for Explosives Safety (USATCES) and the DDESB help ensure explosives safety while an MR is being conducted by ensuring the adequacy of protective measures and compliance with DoDM 6055.09 (DDESB, 2008). The USATCES formally reviews, evaluates, and provides Army approval of measures to protect Army employees and the public from the potential hazards associated with MR. USATCES also ensures that the design of an MR addresses any residual explosive hazards potentially present at an MRS after completion of such responses, for example through the use of LUCs.

12.5.2. In summary, if there is potential for a completed MEC or MC source-to-receptor pathway, the following hazard and risk mitigation measures can be applied:

a. Reducing the quantity of MEC and MC on site lowers the risk.

b. Reducing the number of potential receptors on site lowers the risk.

c. Reducing the potential for interaction between receptors and MEC and MC lowers the risk (e.g., LUCs).

d. Modifying or controlling the behavior of the receptors lowers the risk.

12.6. Risk Communication.

12.6.1. Effective communication is an integral part of hazard and risk management, collectively referred to as risk communication. Early, effective communication of hazards and risk allows the public to have a stake in the decisions made and increase the likelihood of gaining community support. When the public perceives the government as being unresponsive and community relationships are poor, the public tends to judge the risk as being more serious. Without effective risk communication, the level of risk has little effect on the public's perception of risk and increasing the amount of technical detail has no effect on the perceived risk. Section 2.2 of this manual provides information on the TPP process, which guides risk communication to the project stakeholders.

12.6.2. Critical to effective risk communication is early stakeholder involvement. Restoration Advisory Boards (RABs) frequently are available as a means to facilitate public involvement and to implementing effective communication. RABs are advisory groups for the environmental restoration process and may involve representatives from the DoD, USEPA, state and local governments, tribal governments, and the affected local community. Although RABs are not decision-making bodies, the RAB members share community views and enable the continuous flow of information. The PDT should plan to have a risk assessment presentation to the RAB, if one is active at the installation. Assistance with this presentation can be provided by an expert from the EM CX, if required. Additional information on developing a public participation plan can be found in EP 200-3-1.

12.6.3. There are many ways to effect risk communication; because of the differences in the education, interest level, and knowledge of the audience, more than one communication venue may be appropriate. The PDT should consider designating one person as a communications coordinator. This person could be from the public affairs office or a RAB member and does not necessarily have to be a technical expert. The communications coordinator should become knowledgeable about MEC hazard and MC risk assessment issues and know when and where to go for additional expertise. At the beginning of a project, the PDT and communications coordinator should develop a site-specific risk communications plan. Components of the plan may utilize different methods of risk communication, including presentations, videos, partnering meetings, public information forums, and printed media.

12.7. Long-Term Management of Residual Hazards.

12.7.1. A CERCLA 5-year review is required for all MR projects where the final remedy does not allow for unlimited use and unrestricted exposure.

12.7.2. The purpose of the 5-year review is to determine, on a periodic basis not to exceed 5 years, if the selected remedy remains protective of human health, safety, and the environment. Refer to EP 200-1-18 for procedural guidance on conducting 5-year reviews at MRSs.

# CHAPTER 13

## Project Reporting Documents

13.1. Introduction.

13.1.1. This chapter provides guidance on the preparation and content of reports and deliverables developed during the execution of MR projects. See Chapter 4 for information about the requirements and content of key project planning documents.

13.1.2. Some reports and deliverables have specific formatting requirements that will be specified in a contract's data requirements.

13.1.2.1. RI and FS Reports. The Army RI/FS Guidance Document provides the content and format requirements for RI and FS Reports.

13.1.2.2. After Action Report (AAR). An AAR is used to provide the results of MR RA and removal actions or other munitions-related operations and activities, as required. It documents all activities and operations that occurred and lists the MEC found during the RA or removal action and the MEC locations and the actions taken to address MC contamination. If an Emergency Action has been taken, the EOD unit conducting the removal action will have prepared an EOD Incident Report; if so, this incident report should be included in the AAR.

13.1.2.3. Institutional Analysis. EP 200-1-20 (EP 1110-1-24) and ER 200-3-1 contain information on the requirements for conducting an institutional analysis to support development of proposed Land Use Controls as part of a removal or remedial response.

13.1.2.4. Accident/Incident Reports. EM 385-1-1, EM 385-1-97, ER 385-1-99, and the applicable regulations at 29 CFR 1904 contain requirements for preparing reports of accidents or incidents that occur on the work site or in connection with the work conducted as part of the execution of a SOW/PWS.

13.1.2.5. Periodic Status Reports. Periodic status reports include weekly and monthly status reports. A monthly status report, consisting of a progress report and an exposure data report, is for reporting project status prior to and after completion of fieldwork. A weekly status report is for reporting project status from the beginning through completion of fieldwork.

13.1.2.6. Minutes / Record of Meeting. Minutes / records of meetings record the proceedings of meetings and are used to provide a written record of attendees, questions and answers from public meetings, and other information and should be submitted within 5 days after the meeting. Sections should include a title page (meeting date, meeting title, project title, contract/task number, signatures), report minutes (purpose/objectives of meeting, and agenda), administrative data (date and location, sponsoring agency, name and title of chairperson, names and titles of attendees), covered information (description of material discussed), nature of discussion, and resulting actions.

13.1.2.7. Record of Conversation. Telephone conversations / correspondence records should be used to record the contents of substantive telephone conversations and written correspondence, including all calls to and from government personnel that require action by either the government or the contractor; all calls to or from government personnel that directly or indirectly affect contract terms and conditions; all calls to or from federal, state, or local regulatory agency personnel; and all calls to contractor personnel from outside sources that require the calling party to be referred to a USACE Public Affairs Office.

13.1.2.8. Personnel Qualifications Certification Letter. The requirements for a contractor-submitted letter certifying that key personnel and personnel filling core labor categories meet the training and experience requirements for the position held include a list, by name and position, of all individuals filling key personnel positions and core labor categories; the following certifying statement: "I certify that the personnel listed meet or exceed contract requirements for the functions they will perform"; and resumes to document the qualifications for the key personnel and personnel filling core labor categories. Resumes must document all required educational and experience requirements as listed in the contract. Resumes for UXO personnel shall be accompanied by the EOD school course graduation certificate or the UXO Tech 1 certification certificate.

13.1.2.9. Guidance. The following sections provide guidance on the content requirements for the following MR project reports, deliverables, and submissions prepared after the completion of project activities:

a. Reporting the results of cultural resources field survey (see Sections 13.2.1 and 13.2.2)

b. Reporting the results of cultural resource monitoring activities (see Section 13.2.3)

c. Reporting the results of biological field survey (see Sections 13.3.1 and 13.3.2)

d. Reporting the results of biological avoidance activities (see Section 13.3.3)

e. Reporting the results of applying the MRSPP (see Section 13.4)

f. GDS data deliverables (see Section 13.5)

g. Instrument Verification Letter Report (see Section 13.6)

h. Geophysics data deliverables (see Section 13.7)

i. MC data deliverables (see Section 13.8)

13.2. Cultural Resources Reporting.

13.2.1. Initial Survey Results.

13.2.1.1. If cultural resource concerns are not present at the site after the initial cultural resources survey is completed (see Section 4.7.4.12), written communication to applicable regulatory agencies shall be completed and submitted with site information and the completed checklist and stating further cultural resource investigations (i.e., a field survey) would not be necessary. The conclusion of the letter shall be that additional coordination is not intended with those agencies; however, if the agencies identify cultural resource concerns that the USACE team did not, a meeting to address those concerns should be held. In addition, the results of the initial cultural resources survey shall be documented in a survey report, which should include specific information about cultural resources associated with the MRS.

13.2.1.2. If cultural resource concerns are present at the site based on the results of the initial cultural resources survey, written communication to applicable regulatory agencies shall be completed and submitted with site information and the completed checklist. The outcome shall be a meeting with the appropriate regulatory agencies to clarify cultural resource concerns relevant to the project, particularly areas impacted.

13.2.2. Field Survey Results.

13.2.2.1. The results of the cultural resources field survey, if performed, shall be documented in a field survey report, which should include specific information about cultural resources associated with the MRS. The reported information also shall include archaeological site forms, if appropriate, and field notes of the site archeologist.

13.2.2.2. At a minimum, the cultural resources survey information shall include:

a. cultural resource monitoring results, including any excavation results;

b. a general description of cultural resources associated with the MRS (no specific location or figures may be included). This information shall be incorporated into the phase-specific report for the project; and

c. specific information about cultural resources associated with the MRS, to include GPS locations, figures, GIS data, etc. This shall include field notes of the site archeologist. This submittal shall be separate and considered “For Official Use Only” and provided on limited distribution to SHPO/THPO and USACE only.

13.2.3. Monitoring Results. The results of cultural resources monitoring, performed IAW the Cultural Resources Monitoring Plan (Section 4.7.4.12.6), shall be documented in the associated phase-specific report.

13.3. Ecological Resources Reporting.

13.3.1. Initial Survey Results. If ecological concerns are not present at the site based on the results of the initial Ecological Resources Survey (see Section 4.7.4.11.8), written communication to applicable regulatory agencies shall be completed and submitted with site information and the completed checklist.

13.3.1.1. The conclusion of the letter shall be that additional coordination is not intended with those agencies; however, if the agencies identify ecological concerns that the USACE team did not, a meeting to address those concerns should be held.

13.3.1.2. If ecological concerns are present at the site, written communication to applicable regulatory agencies shall be completed and submitted with site information and the completed checklist. The outcome shall be a meeting with the appropriate regulatory agencies to clarify ecological concerns relevant to the project, particularly sensitive receptors, breeding seasons, areas impacted, etc.

13.3.2. Field Survey Results. The results of the ecological resources field survey, if performed, shall be documented in a field survey report, which should include specific information about biological resources associated with the MRS. The report should include specific information about the biological resources associated with the MRS, such as species identified, populations, critical habitat, etc. The report also shall include field notes of the site biologist.

13.3.3. Biological Avoidance Results. The results of biological avoidance activities performed during site activities shall be documented in the associated phase-specific report.

13.4. Munitions Response Site Prioritization Protocol.

13.4.1. In response to a 2002 National Defense Authorization Act requirement, DoD developed the MRSPP as the methodology for prioritizing sites known or suspected to contain MEC or MC for response actions. Each component must apply the protocol to determine a relative priority for MRSs located at active installations, BRAC installations, FUDS, or other properties no longer under DoD control. The priority assigned should be based on the overall conditions at each site, taking into consideration various factors relating to the potential environmental and safety hazards.

13.4.2. The MRSPP consists of the following three modules to evaluate the unique characteristics of each hazard type:

a. The Explosive Hazard Evaluation Module addresses explosive hazards posed by MEC and MC in high enough concentrations to pose an explosive hazard.

b. The CWM Hazard Evaluation Module addresses hazards associated with the effects of CWM.

c. The Health Hazard Evaluation (HHE) Module addresses chronic health and environmental hazards posed by MC and incidental nonmunitions-related contaminants.

13.4.3. Site prioritization of an MRS using MRSPP is applied as soon as the modules can be scored and would, for a new site, typically be done at the PA phase, although the HHE module may have the alternative rating of "evaluation pending" due to lack of MC data. The MRSPP for an MRS is further developed during the SI phase and updated during later phases, including the RI phase within the CERCLA process. The MRSPP results serve as the basis for an installation's or USACE District's input to overall program planning, budget development, and execution decisions. The MRSPP for a site must be reviewed annually and updated, as needed. For FUDS sites, the MRSPP score sheets must be filled in using FUDSMIS.

13.4.4. The MRSPP Wizard is an available tool that may be used to complete the MRSPP analysis. Its use may be a requirement on some contracts, including FUDS. The MRSPP Wizard is available at http://www.lab-data.com/MRSPP/Login.aspx?returnURL=default. The MRSPP Primer provides details about the MRSPP and should be consulted, along with other policy and guidance: http://denix.osd.mil/mmrp/upload/MRSPP_Primer.pdf.

13.4.5. The USACE FUDS Handbook on Realignment, Delineation, and MRS Prioritization Protocol Implementation (2011) provides guidance on realignment and delineation procedures as well as MRSPP implementation. While the handbook's applicability is for FUDS projects, the guidance outlined within it may be extended to non-FUDS projects.

13.4.6. Documentation of MRSPP results should be provided first in the PA report (if applicable) and maintained in the Administrative Record, which also should include any information provided by stakeholders that influence the relative priority assigned to an MRS or sequencing decisions concerning an MRS. The Administrative Record also should contain the following:

a. Notification to USEPA, other federal agencies, state regulatory agencies, tribal governments, and local government organizations, as appropriate, seeking their involvement in MRSPP's application and MRS sequencing

b. Announcements in local community publications requesting information pertinent to prioritization or sequencing

c. Any information provided to stakeholders that may influence the relative priority assigned to an MRS or sequencing decision concerning an MRS

MRSPP scores also are required to be uploaded into the applicable database of record, including AEDB-R, HQAES, and FUDSMIS.

13.5. Geospatial Data and System Deliverables.

13.5.1. All GDS deliverables and maps will be submitted IAW contract requirements. When applicable, maps and deliverables will be submitted in electronic format. The following sections provide guidance on the maps and deliverables that will be submitted.

13.5.2. The following deliverables will be submitted to the PDT following the location survey and mapping task (the submittal dates should be specified for each delivery order).

13.5.2.1. Original copies of all field books, layout sheets, computation sheets, abstracts and computer printouts

13.5.2.2. Tabulated listing of all project control markers established and/or used in support of the MR showing adjusted horizontal and vertical positional values in meters and feet

13.5.2.3. Tabulated listing of all MEC recovered and any specific anomalies not completely investigated

13.5.2.4. Tabulation of MC sample locations included in the project

13.5.2.5. Completed monument descriptions, stored in the GIS database, spreadsheet, etc.

13.5.2.6. Unique items created and/or used to create the end products and the narrative and description required by the SOW

13.5.2.7. Required location, project, and grid maps

13.5.2.8. Image files of the aerial photographs taken for the project, if aerial photography is required in the SOW

13.5.2.9. All maps will be prepared using industry standard sheet sizes and formats. Project-specific reporting requirements may dictate the use of a variety of sheet sizes to show relevant information. The PDT will determine the number of maps and copies of digital data to be delivered to the MMDC.

13.5.2.10. No digital data will be acceptable until proven compatible with the GDS designated in the SOW. All revisions required to achieve compatibility with the SOW-designated GDS will be done at the contractor's expense.

13.5.2.11. Deliverables will be submitted to the PDT IAW contract requirements. Whenever appropriate, deliverables should be submitted electronically. Deliverables that should be submitted upon completion of the munitions response project include:

13.5.2.12. Unique items created and/or used to create the end products and the narrative and description required by the SOW

13.5.2.13. Digital data in the media as specified in the SOW (nonproprietary data file formats on stable digital media) along with all other supporting files and a data manual documenting all production and work files

13.5.3. In all development of GDS data, consideration shall be made to address the life cycle data management aspects of the development, modification, storage, and reuse of geospatial data. Metadata shall be complete and thorough to allow publication of an individual dataset through any one of the following sources:

13.5.3.1. National Geospatial Data Clearinghouse (Clearinghouse) – a distributed, electronic network of geospatial data producers, managers, and users operating on the Internet. The Clearinghouse is a key element of EO 12906 and allows its users to determine what geospatial data exist, find the data they need, evaluate the usefulness of the data for their applications, and obtain or order the data as economically as possible.

13.5.3.2. USACE Clearinghouse Node – HQUSACE established and maintains a computer network server on the National Geospatial Data Clearinghouse. This node functions as the primary point of public entry to the USACE geospatial data discovery path in the Clearinghouse. A separate electronic data page for each USACE Command has been established on the server.

13.5.4. The PDT should review the extent of mapping requirements to be included in each MR project SOW. The PDT should assure that the SOW states that all maps and drawings to be provided under the task are sealed and signed by the RLS/PLS. The Tri-Service CADD/GIS Technology Center's SDSFIE should be specified for all location survey and mapping deliverables of CADD, GIS, and other spatial and geospatial data IAW EM 1110-1-2909. The PDT will ensure that the following maps are provided:

a. Location Maps. A location map showing the project location and surrounding points of interest will be required. The map(s) should be produced at a scale no smaller than 1:2400 or 1":200' (or 1:2500 for metric scale).

b. Hard copy project maps.

c. A map of all project-related points of interest should be produced and delivered at a scale specified by contract requirements. The project map should show the location and identification of all of the project control monuments recovered and/or established at the project property in support of the munitions response, local project controls, significant planimetric features, project boundaries, and property boundaries (if in close proximity to project boundaries). The location of recovered MEC also should be plotted and identified on the map unless individual grid maps also are required.

d. Grid Maps. If required, individual maps for each grid should be prepared at a scale no smaller than 1:2,400 or 1":200' (or 1:2500 for metric scale). The Grid Maps will include the plotted location of each surface MEC and verified subsurface MEC recovered and each subsurface geophysical anomaly within the grid not completely investigated and any environmental samples. Other notable planimetric features within the grid will also be sketched on the individual Grid Maps.

13.5.4.1. General Project Map requirements also should include grid, magnetic, and true north arrows with their angular differences; grid lines or tic marks at systematic intervals with values shown on the edges of the map; and a legend showing the standard symbols used for the mapping. Each sheet also will have a standard border, a revision block, and a complete index sheet layout.

13.5.4.2. All production and work files, as well as all supporting data, will be fully documented into a concise data manual. This manual will include all specific information required for an outsider to be able to recreate all products and determine the location, names, structures and association of the data. The manual will be included as an ASCII file titled READ.ME that is included with all distributed digital data.

13.6. <u>Instrument Verification Strip / Geophysical Prove-Out Letter Report</u>.

13.6.1. After the completion of the IVS or GPO, the contractor must prepare an IVS letter report or GPO letter report, respectively. See Chapter 6 for information on when an IVS or GPO should be used and when each is applicable. The general requirements for these are the same. The letter report must contain all information required by the PDT to support anomaly selection decisions and include the following:

a. As-built drawing of the IVS or GPO test plot

b. Pictures of all seed items

c. Geophysical data maps

d. Average peak responses for IVS seeds

e. Blind QC seed minimum responses

f. Static spike values

g. Summary of the IVS or GPO results

h. Proposed geophysical equipment, techniques, and methodologies (for GPO only)

i. Anomaly selection criteria

j. Instrument specific and process specific criteria for defining the quality of the geophysical data (GPO only)

k. Any other pertinent data/information used in the decision making process

13.6.2. A compact disk should be delivered to the USACE geophysicist with the letter report and containing the following files:

a. IVS or GPO Letter Report in Microsoft Word format

b. All raw and processed geophysical data

c. Geophysical maps in their native format (e.g., Surfur®, Geosoft Oasis Montaj™, Intergraph, or ESRI ArcView format) and as raster bit-map images such as BMP, JPEG, TIFF, or GIF

d. Seed item location table in Microsoft Excel or Access format

e. Microsoft Access tables IAW USACE database table format that includes entries in the seed item table for target IDs per dataset

f. Table in Microsoft Access format of all control points, survey points, and benchmarks established or used during the location surveying task

13.6.3. The IVS (or GPO) letter report should be included in future UFP-QAPPs and reports associated with the survey area. If the contractor proceeds with production geophysical mapping prior to the government's acceptance of their IVS (or GPO) Letter Report, they proceed at their own risk. If the government rejects any portion of the contractor's Letter Report pertaining to geophysical mapping procedures, QC or detection capabilities, all data collected by the contractor at their own risk should be rejected and the contractor shall re-collect the data at zero cost to the government.

13.7. Geophysics Data Deliverables.

13.7.1. General. The geophysical data formats in the following sections are required to be followed, although additional data formats may be delivered to the PDT. The contractor must follow exactly the formats specified in this paragraph, although the contractor may choose to submit the data in additional formats as well. All geophysical data shall be accompanied by metadata in the form of a read-me file or a database or spreadsheet table documenting the field activities associated with the data, the processing performed, and correlation of data file names to grid names used by other project personnel. Metadata shall be generated for each logical grouping of data (e.g., names and contents of all files generated to map a grid, or names and contents of all files generated from a towed platform during a mapping session). Metadata shall fully describe all measurements recorded in each data file and shall include all information necessary to successfully associate all geophysical system measurements to their correct geographical location. At the discretion of the PDT, the metadata can be limited to provide references to where this information is located.

13.7.2. Raw Geophysical Field Data Format and Storage. Raw field data will be stored in a logical file directory (folder) structure to facilitate its management and dissemination to PDT members. Raw field data are defined as all digital data generated from the geophysical system and includes geophysical, positioning, heading, tilt, and any other peripheral or instrument measurements collected or recorded during data acquisition. All raw field data shall have a time stamp associated with each measurement event. At the discretion of the PDT, raw field data may include geophysical system data that have been checked, corrected, and processed into ASCII files, either individually by instrument or merged with positioning data. Metadata for raw geophysical data shall include instructions for generating ASCII formatted data from all raw data for use in computer processing systems.

13.7.3. Final Processed and Advanced Processed Data Format and Storage. Final and Advanced (as required) processed data shall be produced and presented in ASCII formatted files and native geophysical processing software formats (e.g., Geosoft GDB). Final processed data are defined as data that represent, to the best of the contractor's ability, the true potential field that exists at each actual location measured by the geophysical system. Final processed data shall have all corrections applied needed to correct for positioning offsets, instrument bias (including instrument latency), instrument drift, roll-pitch-yaw-angle offsets, and diurnal magnetic variations. Advanced processed data are defined as Final Processed data that have been subjected to additional advanced processing (e.g., filtering) techniques and were used in the anomaly selection process. All corrections and processing steps will be documented. Metadata for final processed and advanced processed data shall include UTM zone and coordinate units (the PDT or PWS may require additional coordinate units and projections be included), and descriptions and units of all “z” values, which are the data associated with each measurement event. All measurement events shall have a time stamp. Unprocessed, interim-processed, final processed, and advanced processed (if used) “z” values shall be included in a single file. Data file size should be limited to 100 megabytes (Mb) or less, and the file length should be limited to 600,000 lines or less. Each data file will be named logically and sequentially so that the file name can be correlated easily with the project-specific naming conventions used by the PDT.

13.7.4. Anomaly Table, Dig Selection Table, Reacquisition Table and Intrusive Results Table Formats. The anomaly, dig selection, and intrusive results shall be submitted digitally in a Microsoft Access database IAW the PWS/SOW and appropriate data item descriptions. The current database template includes tables that document Project Start-up parameters (e.g., project location, contractor name, coordinate system), Daily/Dataset Quality Results (e.g., along line spacing, background noise, coverage), Dataset Tracking (e.g., filename, location, terrain, data processing parameters), and Anomaly/Dig Results (e.g., reacquisition parameters, intrusive results).

13.7.5. Data Submittals. The contractor shall furnish for inspection all geophysical data, geophysical maps, and dig sheets via Internet using file transfer protocol, e-mail attachment for small files under 5 Mb, compact disk (CD) / digital video disk (DVD) or other approved method. All geophysical data shall be accompanied by metadata as described above. The delivery schedule shall be IAW contract-specific requirements unless otherwise established by the PDT. The contractor also shall provide a digital planimetric map in software that is capable of providing output in the approved format and coincident with the location of the geophysical survey, so that each day's geophysical data set can be registered within the original mission plan survey map. Each data submittal shall include the MS Access database tables to identify the quality of the data and whether it is meeting project objectives. Any QC failures shall be identified, and the corrective action that is being taken shall be described. The final report deliverable shall include two copies on CD/DVD of all project data.

13.7.5.1. Geophysical data maps should be prepared for each grid or transect within the investigation in both an editable form (e.g., Geosoft .map file) and in a common image format (e.g., JPEG). Geophysical data maps should include all of general site features (excluding dig results), plus the following necessary site information:

a. All selected targets and known features shall be marked with symbols on the map.

b. Map scales should be even multiples of the base units presented in the maps.

c. Map sizes should be designed to fit standard printer or plotter sizes.

d. Grid ticks or grid lines should be visible and labeled.

13.7.5.2. The title block of the geophysical map should include:

a. figure number;

b. the map title and subtitle (e.g., instrument and type/component); and

c. the location of the information being presented (e.g., site/area name and property/grid identification);

13.7.5.3. The legend of the geophysical maps should include:

a. all objects/symbols shown on the map;

b. map scale bar, coordinate system, and north arrow; and

c. color scale bars that use a color scheme that clearly differentiates between anomalies and background readings (e.g., white or gray background readings). A classic "cold to hot" color scale should be used with negative values plotted in blue and high positive values plotted in red/pink. The range of values should be fixed so that the same color scale is utilized across the site.

13.7.5.4. Additional project information on the geophysical map should include boxes for the following information:

a. Client

b. Project

c. Contractor

d. Map creator

e. Map approver

f. Date created

13.8. Munitions Constituents Data Deliverables.

13.8.1. Introduction. MC data are reported throughout a project's life cycle. The following sub-sections further discuss the MC reporting requirements.

13.8.2. Field Reporting.

13.8.2.1. During field sampling, Data Quality Control Reports (DQCRs) must be prepared. At a minimum, copies must be sent daily electronically to the Contracting Agency (the PM, technical manager (TM), and project chemist) and the geographic district.

13.8.2.2. DQCRs must include site activities, descriptions of samples collected, and instruments and equipment utilized. Any deviations from the approved UFP-QAPP should be documented in the DQCRs, including a description of the problems encountered, corrective action taken, and a summary of any verbal or written instructions received from government personnel. Any deviations that may affect DQOs must be conveyed to USACE personnel (TM, project chemist, etc.) immediately.

13.8.2.3. The following should be attached to the DQCRs: QA sample tables that match up primary, replicate (QA/QC), and other field control samples (e.g., blanks), copies of chain-of-custody forms, and any other environmental sampling-related project forms that are generated. DQCRs become part of the project file.

13.8.3. Reporting Analytical Results.

13.8.3.1. Data Reporting Standards and Requirements.

13.8.3.1.1. All laboratory data for samples analyzed by commercial laboratories must be submitted in the SEDD format unless the PWS/SOW states otherwise. Details on the SEDD format are provided in SEDD Version 5.2 (or most recent version) (http://www.epa.gov/fem/sedd.htm). SEDD Version 5.2 is the required submittal format for FUDS projects. Other project-specific electronic data deliverable (EDD) requirements should be documented in the project SOW/PWS. The following software can be made available as government furnished software if deemed required by the PDT as specified in the SOW/PWS: Environmental Data Management System, MRSPP Wizard, and Forms II Lite. Use of the MRSPP Wizard is mandatory if MRSPP preparation is part of the SOW/PWS.

13.8.3.1.2. The SEDD-formatted deliverable should be evaluated by review software that meets minimum criteria (i.e., capability to maintain SEDD integrity through the review, to provide a reviewed SEDD file for archiving, and to maintain a project-specific library file (e-QAPP) that can be managed with each deliverable). This software is not available as a government furnished item and contractors are not constrained to any proprietary system, as long as it meets those requirements. Such software is intended to automate certain data review functions that are strictly comparisons to numeric criteria (e.g., holding time compliance, comparison to recovery/relative percent difference limits). Use of automated review software requires that the contractor develop a comprehensive library file (e-QAPP) for all of the methods to be analyzed under the SOW/PWS. The library file should accurately reflect all of the analytical quality requirements as documented in the final sampling and analysis planning document for the project and should be provided to both MMDC and the subcontract lab for use in screening EDD submittals. The electronic deliverable must include appropriate data flags resulting from laboratory review and contractor's data validation. All electronic data submitted by the contract laboratory is required to be error-free and in complete agreement with the hardcopy data. Data files are to be delivered IAW contract requirements. They should be submitted with a transmittal letter from the laboratory that certifies that the file is in agreement with hardcopy data reports and has been found to be free of errors using the latest version of corresponding evaluation software provided to the laboratory. The contract laboratory, at their cost, should correct any errors identified by MMDC. The contractor is responsible for the successful electronic transmission of field and laboratory data. The laboratory is responsible for archiving the electronic raw data, associated software, and sufficient associated hardcopy data (e.g., sample login sheets and sample preparation log sheets) to completely reconstruct the analyses that were performed for the period specified after completion of the applicable contract. If no period is specified, laboratories should keep data for 10 years.

13.8.3.1.3. The following files shall be provided for a complete EDD:

- Library file (must be project-specific)
- DTD file
- SEDD Stage 2A or 2B XML file (consistent with SEDD Version 5.2 valid values)
- Post-review SEDD files
- Annotated error log
- MRSPP Wizard export file (not required if MRSPP preparation is not part of the SOW/PWS

13.8.3.1.4. Acceptance of these files will be based on the following:

- The error log generated by the reviewer matches the error log provided by the contractor.
- The reviewed files shall be consistent with flagged data tables provided in the report. If there are manually derived data flags (from hard copy review), they must be documented in the reviewed data file.
- Where more than one analysis is submitted for a sample, it is clear which analytical result is being reported. The final electronic submittal must clearly indicate the single data point that is the "best" data point for each analysis.

13.8.3.2. Final Report Requirements.

13.8.3.2.1. Contractors should submit the complete data packages to the MMDC and reference them as part of the larger study report. Unless otherwise directed by the PDT regarding placement, the Chemical Data Final Report (CDFR) must be provided as an appendix to the final report. The items listed above are required to be submitted with the report. The CDFR must be produced, including a summary of QC practices employed and all chemical parameter measurement activities, after project completion.

13.8.3.2.2. As a minimum, the CDFR must contain the following:

- Summary of project SOW
- Summary of any deviations from the design chemical parameter measurement specifications
- Summary of chemical parameter measurements performed as contingent measurements
- Summary of success or failure in achieving project-specific DQOs

- Presentation and evaluation of the data, to include an overall assessment on the quality of the data for each method and matrix. This should include, at a minimum, two types of data tables. The first shall include all analytical results for all samples collected. The second must include all analytical results greater than the LOD for all samples collected. Tables should be sorted by method and include appropriate data flags resulting from laboratory review and from the contractor's data validation.

- Internal QC data generated during the project, including tabula summaries correlating sample identifiers with all blank, MSs, surrogates, duplicates, LCSs, and batch identifiers.

- A list of the affected sample results for each analyte (indexed by method and matrix), including the appropriate data qualifier tag (J, B, R, etc.) where sample results are impacted negatively by adverse QC criteria.

- Summary of field and laboratory oversight activities, providing a discussion of the reliability of the data, QC problems encountered, and a summary of the evaluation of data quality for each analysis and matrix as indicated by the laboratory QC data and any other relevant findings

- Comparison of results to any applicable project-specific numeric criteria

- Conclusions and recommendations

- Appendices containing (1) chemistry data package and (2) DQCRs

13.8.3.3. Documentation Records.

13.8.3.3.1. Documentation records must be provided as factual evidence that required chemical data have been produced and chemical data quality has been achieved.

13.8.3.3.2. The documentation must comply with the requirements specified in the discussions above on the QAPP, the DQCRs, the Chemistry Data Package, the EDD, and the CDFR.

13.8.3.4. Environmental Restoration Information System (ERIS).

13.8.3.4.1. The ERIS is a Web-based database system for the storage of Army environmental restoration and range field data. It serves as a central repository for the Army installation chemical, geological, and geographical data. The ERIS is maintained by the USAEC, and all military installations that use Environmental Restoration, Army funds are required to upload their data to the system. ERIS is accessed through the USAEC Army Environmental Reporting Online portal using a CAC card at https://aero.apgea.army.mil.

13.8.3.4.2. If data collected as part of an MR action need to be uploaded to ERIS, the PDT should review the ERIS data specifications during the planning phases of the project and ensure that the laboratory will provide EDDs that are compatible with ERIS and that geographical and geological data are recorded in a format that is compatible with ERIS.

# APPENDIX A

# References

## A.1. Required References.

### A.1.1. Public Laws

Abandoned Shipwreck Act of 1987, 43 U.S.C. § 2101 - 2106

American Indian Religious Freedom Act of 1978, as amended, 42 U.S.C. § 1996

Antiquities Act of 1906, 16 U.S.C. § 431 - 433

Archeological Resources Protection Act of 1979, 16 U.S.C. § 470aa – 470mm

Base Realignment and Closure Act of 1988, 10 U.S.C. § 2687.

Clean Air Act, 42 U.S.C § 7401 – 7671q

Coastal Zone Management Act of 1972, 16 U.S.C. § 1451-1464

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. § 9601.

Confidentiality of the Location of Sensitive Historic Resources, 16 U.S.C. § 470w-3(a)

Conservation of Cultural Resources: Antiquities Act of 1906. 16 U.S.C. § 431-433

Defense Base Realignment and Closure Act of 1990, PL 101-510, 104 Stat. 1808.

Defense Environmental Restoration Program, 10 U.S.C. § 2701, et seq.

Endangered Species Act of 1973, 16 U.S.C. § 1531 - 1544

Federal Insecticide, Fungicide, and Rodenticide Act, 7 U.S. C § 136

Federal Land Policy and Management Act of 1976, 43 U.S.C. § 1701 - 1787

Federal Water Pollution Control Act (commonly referred to as Clean Water Act), 33 U.S.C. § 1251 - 1387

Fish and Wildlife Coordination Act, 16 U.S.C § 661 - 668

Historic Sites, Buildings and Antiquities Act, 16 U.S.C. § 461 - 470

Inventory of Unexploded Ordnance, Discarded Military Munitions, and Munitions Constituents at Defense Sites (other than operational ranges), 10 USC § 2710(e)(3)

Magnuson-Stevens Fishery Conservation and Management Act, 16 U.S.C. § 1801 – 1891d

Marine Mammal Protection Act of 1972, 16 U.S.C. § 1361 – 1423h

Marine Protection, Research, and Sanctuaries Act of 1972, 33 U.S.C. § 1401-1445

National Historic Preservation Act of 1974, 16 U.S.C. § 470

National Pollutant Discharge Elimination System, 33 U.S.C. 1342

Native American Graves Protection and Repatriation Act, 25 U.S.C. § 3001 - 3013

Oil Pollution Act, 46 U.S.C. § 2101

Religious Freedom Restoration Act of 1993, 42 U.S.C. § 2000bb – 2000bb4

Resource Conservation and Recovery Act of 1976, PL 94-580, 90 Stat 2796, 42 U.S.C. § 6901, et seq., as amended.

Rivers and Harbors Act of 1899, 33 U.S.C. §§ 401, 403, 407

Safe Drinking Water Act, 42 U.S.C. § 300f

Superfund Amendment and Reauthorization Act (SARA) of 1986, PL 99-499, 100 Stat 1613, amending CERCLA, 42 USC § 9601 et seq., and miscellaneous other sections.

Toxic Substances Control Act, 15 U.S.C. § 2601 - 2697

Wild and Scenic Rivers Act, 16 U.S.C. § 1271-1287

A.1.2. Executive Orders

Executive Order 12580, Superfund Implementation
http://www.archives.gov/federal-register/codification/executive-order/12580.html

Executive Order 13007, American Indian, Eskimo, Aleut, or Native Hawaiian Sacred Sites
http://www.nps.gov/history/local-law/eo13007.htm

Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management http://www.epa.gov/oaintrnt/practices/eo13423.htm

Executive Order 13514, Federal Leadership in Environmental, Energy, and Economic Performance http://www.gpo.gov/fdsys/pkg/FR-2009-10-08/pdf/E9-24518.pdf

A.1.3. Regulations

ATFP 5400.7
Federal Explosives Law and Regulations

DFARS Part 245
Government Property

DFARS Subpart 252.223-7004
Drug Free Work Force
http://www.acq.osd.mil/dpap/dars/dfars/html/current/252223.htm#252.223-7004

FAR Part 9.106-4(d)
Reports

FAR Part 37
Service Contracting
http://www.acquisition.gov/far/current/html/FARTOCP37.html#wp223485

FAR Part 37.102
PBA Policy

FAR Part 37.6
Performance Based Acquisition
http://www.acquisition.gov/far/current/html/Subpart%2037_6.html#wp1074195

FAR Subpart 45.5
Management of Government Property in the Possession of Contractors
https://acquisition.gov/far/0219/html/Subpart_45_5.html

FAR Part 46
Quality Assurance

FAR Part 46.103
Contracting Office Responsibilities

Title 10 CFR Parts 20 and 40
Standards for Protection Against Radiation/Domestic Licensing of Source Material

Title 29 CFR Part 1910
Occupational Safety and Health Administration Hazardous Waste Operations and Emergency Response

Title 32 CFR Part 179
Munitions Response Site Prioritization Protocol

Title 36 CFR Part 800
Protection of Historic Properties

Title 36 CFR Part 79
Curation of Federally Owned and Administered Archaeological Collections

Title 40 CFR Part 122
National Pollutant Discharge Elimination System (NPDES)

Title 40 CFR Part 261.6
Requirements for Recyclable Materials

Title 40 CFR Part 266.20 (b)
Land Disposal Restriction Treatment Standards

Title 40 CFR Part 300
National Oil and Hazardous Substances Pollution Contingency Plan (NCP)

Title 49 CFR Subchapter C
Department of Transportation Hazardous Materials Regulations

A.1.4. DoD Directives, Instructions, Regulations, Standards and Other Publications

DDESB TP-15
Approved Protective Construction

DDESB TP-16
Methodologies for Calculating Primary Fragment Characteristics

DDESB TP-18
Minimum Qualifications for Unexploded Ordnance (UXO) Technicians and Personnel.

Deputy Under Secretary of Defense (ATL), Interim Guidance on Perchlorate Sampling, 23 September 2003 http://www.cpeo.org/pubs/Perchlorate_Sampling_Interim_Policy.pdf

DoDI 4161.02
Accountability and Management of Government Contract Property
http://www.dtic.mil/whs/directives/corres/pdf/416102p.pdf

DoDD 4715.11
Environmental and Explosives Safety Management on Operational Ranges Within the United States http://www.dtic.mil/whs/directives/corres/pdf/471511p.pdf

DoD 4715.20-M
Defense Environmental Restoration Program Management
http://www.dtic.mil/whs/directives/corres/pdf/471520m.pdf

DoD 6055.09-M
Ammunition and Explosives Safety Standards
http://www.dtic.mil/whs/directives/corres/html/605509m.html

DoD EDQW, Sampling and Testing for Perchlorate at DOD Installations, Interim Guidance, February 2004 http://www.navylabs.navy.mil/Perchlorate.htm

DoD Environmental Data Quality Workgroup Fact Sheet: Detection and Quantitation – What Project Managers and Data Users Need to Know (September, 2009)
http://www.navylabs.navy.mil/Final%20DQ%20Fact%20Sheet%20091409.pdf

DoD Guidebook for Performance-Based Services Acquisition (PBSA) in the Department of Defense. December 2000. http://www.acq.osd.mil/dpap/Docs/pbsaguide010201.pdf

DoD 4715.20-M
Defense Environmental Restoration Program (DERP) Manual
http://www.dtic.mil/whs/directives/corres/pdf/471520m.pdf

DoD Perchlorate Handbook, August 2007
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AR 50-6
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AR 200-1
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AR 385-10
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EM 200-1-10
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EM 200-1-12
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ER 5-1-14
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# APPENDIX B
# QASP TEMPLATE

1.0 Overview.

1.1 Introduction. This performance-based Quality Assurance Surveillance Plan (QASP) sets forth the procedures and guidance that the Contracting Officer's Representative (COR) will use in evaluating the technical and quality performance of the Contractor in accordance with the terms and conditions of the performance work statement (PWS). A copy of the signed final plan will be furnished to the Contractor so that the Contractor will be aware of the methods that the COR will use in evaluating performance of this contract.

1.2 Purpose. The purpose of the QASP is to assure that the performance of specific activities and the completion of project milestones are accomplished in accordance with all requirements set forth in the PWS and outlined in the Project Management Plan (PMP) strategy for Army Quality Assurance. This QASP describes the mechanism for documenting noteworthy accomplishments or discrepancies for work performed by the Contractor. Information generated from COR's surveillance activities will directly feed into performance discussions with the Contractor. The intent is to ensure that the Contractor performs in accordance with performance metrics set forth in the contract documents, the Army receives the quality of services called for in the contract, and the Army only pays for acceptable services received.

The QASP is intended to accomplish the following:

1. Define the role and responsibilities of participating Army officials.
2. Define the key milestones, deliverables, and standards that will be assessed.
3. Describe the surveillance methodology that will be employed by the Army in assessing the Contractor's performance.
4. Describe the surveillance documentation process and provide copies of the forms that the Army will use in evaluating the Contractor's performance.
5. Outline quality assurance procedures to be employed by the Government during performance of this task order to confirm that the site characterization is conducted utilizing proper procedures and in accordance with the approved work and safety plans.
6. Define Exceptional, Very Good, Satisfactory, Marginal, and Unsatisfactory performance standards for key milestones, deliverables, and standards
7. Outline corrective action procedures
8. Describe payment procedures.

2.0 Roles and Responsibilities of Quality Assurance Army Officials.

2.1 Contracting Officer. The Contracting Officer (KO) has overall responsibility for overseeing the Contractor's performance. The KO is responsible for the day-to-day monitoring of the Contractor's performance in the areas of contract compliance, and contract administration; reviewing the COR's assessment of the Contractor's performance; and resolving all differences between the COR's assessment and the Contractor's assessment of performance. It is the KO that assures the Contractor receives impartial, fair, and equitable treatment under the contract. The KO is ultimately responsible for the final determination of the adequacy of the Contractor's performance. The KO for this contract is Steve N. McQueen at the U.S. Army Corps of Engineers (USACE), Huntsville District, [insert phone number], [insert e-mail]. Questions for the KO should be directed to the assigned USACE Contracting Specialist, Chester Copperpot at [insert phone number], [insert e-mail].

2.2 Contracting Officer Representative (COR). The Contracting Officer's Representative (COR) is responsible for technical administration of the project and assures proper Army surveillance of the Contractor's performance. The COR is responsible for monitoring, assessing, recording, and reporting on the technical performance of the Contractor on a day-to-day basis. The COR for this contract is Marie B. Curie at the U.S. Army Corps of Engineers (USACE), Huntsville District, [insert phone number], [insert e-mail]. Questions for the COR should be directed to the assigned USACE Project Manager, Stacy Q. Holcombe at [insert phone number], [insert e-mail].

2.3 Technical Expertise and Subject Matter Experts. The KO and COR may call upon the technical expertise of other Army Officials and subject matter experts (SME) as required. These Army Officials and SMEs may be called upon to review technical documents and products generated by the Contractor. For this contract, the following Army Officials and SMEs have been identified:

| | |
|---|---|
| Army Environmental Command | [Insert Name] |
| Camp Swampy | [Insert Name]<br>Restoration Manager |
| Camp Swampy Safety Office | [Insert Name] |
| Local Stakeholders | [Insert Name] |
| USACE, Huntsville District | [Insert Name]<br>USACE Project Manager |
| USACE, Huntsville District | [Insert Name]<br>USACE Project Engineer |
| USACE, Huntsville District | [Insert Name]<br>USACE Senior Geophysicist |
| USACE, Huntsville District | [Insert Name]<br>USACE Industrial Hygienist |
| USACE, Huntsville District | [Insert Name]<br>USACE Project Chemist |
| USACE, Huntsville District | [Insert Name]<br>USACE Risk Assessment |
| USACE, Huntsville District | [Insert Name]<br>USACE Program Manager |
| USACE, Huntsville District | [Insert Name]<br>USACE Ordnance and Explosives Safety Manager |

USACE Environmental and Munitions Center of Expertise
US Army Technical Center for Explosive Safety (USATCES)

DoD Explosive Safety Board (DDESB).

If additional Army Officials and SMEs are identified as work progresses, the QASP will be modified to capture this information.

3.0 Methods for Performance Assessment

3.1 Key Milestones/Deliverables to be Assessed. The following milestones and associated deliverables will be evaluated in accordance with this QASP:

3.1.1 Key Milestones.

- COR acceptance of the Final PMP
- COR acceptance of the Final RI UFP-QAPP for 1 MRS: Training Range Areas 1 and 2 (CASWA-001-R-01)
- COR acceptance of Final Geophysical Data Submittal for 1 MRS: Training Range Areas 1 and 2 (CASWA-001-R-01)
- COR acceptance of Final Dig Sheet Data Submission for 1 MRS: Training Range Areas 1 and 2 (CASWA-001-R-1)
- COR acceptance of Final Munitions Constituents (MC) Data for 1 MRS: Training Range Areas 1 and 2 (CASWA-001-R-1)

- COR acceptance of the Final RI Report for 1 MRS: Training Range Areas 1 and 2 (CASWA-001-R-01)
- COR acceptance of the Final FS Report for 1 MRS: Training Range Areas 1 and 2 (CASWA-001-R-01)

3.1.2 Key Deliverables.

- Project Management Plan (including Waste Minimization Plan)
- Site Safety and Health Plan
- Waste Management Plan
- Sampling and Analysis Plan
- Quality Control Plan
- MMRP Community Relations Plan
- Monthly Status Reports
- Milestone Presentations
- RI UFP-QAPP for Training Range Areas 1 and 2 (CASWA-001-R-01)
- RI Report for Training Range Areas 1 and 2 (CASWA -001-R-01)

3.2 Additional Surveillance Activities. Additional Government surveillance activities may include, but are not limited to, the following:

- Review and approval of meeting minutes from Kickoff Meetings, TPP Sessions, RAB (If required) or Public Involvement Meetings, etc.
- Review of Daily Reports
- Review of data deliverables.
- Oversight of field work activities.
- Review of uploaded electronic deliverables.
- Review of the Contractor's quality control documentation.
- Review of the Contractor's safety records

3.3 Performance Standards. Since cost is fixed in this Delivery Order, the Contractor's performance will be evaluated by assessing the key milestones and deliverables above according to the standards of Quality, Schedule, Management of Key Personnel and Resources, and Stakeholder Concurrence. In addition, the Contractor's performance will be evaluated for the standard of Safety during any fieldwork. For each of these performance standards, the COR will assign one of five ratings of the Contractor's performance: exceptional, very good, satisfactory, marginal, or unsatisfactory, as shown in Table B-1.

Table B-1 - Evaluation Standards

| **Performance Standard** | **Excellent** | **Very Good** | **Satisfactory** | **Marginal** | **Unsatisfactory** |
|---|---|---|---|---|---|
| Basic Definition | Contractor exceeds the performance requirements for the milestone, deliverable, or standard, with no substantive input from the government. | Contractor exceeds the performance requirements for the milestone, deliverable, or standard, with minimal input from the government. | Contractor meets the performance requirements for the milestone, deliverable, or standard, with moderate input from the government. | Contractor meets the performance requirements for the milestone, deliverable, or standard, with significant input from the government. | Contractor does not meet the performance requirements for the milestone, deliverable, or standard, after significant input from the government. |

| Performance Standard | Excellent | Very Good | Satisfactory | Marginal | Unsatisfactory |
|---|---|---|---|---|---|
| **Performance Category: Quality of Product or Service** | | | | | |
| **Quality** | Draft Final and Final deliverables are of excellent quality, approved as submitted, or with no substantive comments limited to grammar, spelling, or terminology. | Draft Final deliverables are of high quality and comments are mostly minor. Final deliverables are approved after one (1) round of Army comments on the Draft Final through acceptance of response to comments table and backcheck of Final report against original comments. No further revisions are required. | Draft Final deliverables are of acceptable quality with only a few number of comments identifying major weaknesses. Final deliverables are approved after two (2) rounds of Army comments on Draft Final . No further revisions are required. | Draft Final deliverables are of poor quality with a significant number of comments identifying major weaknesses or deficiencies. Final deliverables require more than two (2) rounds of Army comments on Draft Final before being approved. (e.g., changes are required to the Final document due to inadequate incorporation of comments). | Draft Final deliverables are of very poor quality and are rejected for resubmittal without comment. Final deliverables did not comply with contract requirements, or one or more document versions required more than three (3) rounds of Army comments before being approved. |
| | Army audit finds that the data collect and/or the work performed exceeds the requirement of the PWS. No deficiencies noted | Army audit of work does not identify any deficiencies that compromise the quality of the data collected or work performed. | Army audit of work identifies deficiencies that do not compromise the quality of the data collected or work performed, and can be corrected. | Army audit of work identifies deficiencies that compromise the quality of the data collected or work performed, but were corrected. | Army audit of work identifies deficiencies that compromise the quality of the data collected or work performed, and cannot be corrected. |
| **Performance Category: Schedule** | | | | | |
| **Schedule** | Contractor Achieves milestone more than 90 days ahead of schedule | Contractor Achieves milestone less than 90 days but more than 30 | Contractor achieves milestone according to the schedule | Contractor achieves milestone more than 30 days but less than 90 days | Contractor achieves milestone more than 90 days behind schedule |

| Performance Standard | Excellent | Very Good | Satisfactory | Marginal | Unsatisfactory |
|---|---|---|---|---|---|
| | (unless the COR waives this requirement), per criteria established in the PWS and this QASP.<br><br>For PMP, excellent rating is achievement of milestone 10 days ahead of schedule. | days ahead of schedule (unless the COR waives this requirement), per criteria established in the PWS and this QASP.<br><br>For PMP very good rating is achievement of milestone 5 days ahead of schedule. | (unless the COR waives this requirement), per criteria established in the PWS and this QASP.<br><br>For PMP satisfactory rating is achievement of milestone on schedule. | behind schedule (unless the COR waives this requirement), per criteria established in the PWS and this QASP.<br><br>For PMP marginal rating is achievement of milestone 10 days behind schedule. | (unless the COR waives this requirement), per criteria established in the PWS and this QASP.<br><br>For PMP unsatisfactory rating is achievement of milestone 15 days behind schedule. |
| **Performance Category: Management of Key Personnel and Resources** | | | | | |
| **Management of Key Personnel and Resources** | All personnel proposed by the contractor were assigned to the project. Some personnel were substituted by higher qualified individuals.<br><br>Zero (0) instances of resource management issues creating a negative impact to | All personnel proposed by the contractor were assigned to the project. Some personnel were substituted by higher qualified individuals.<br><br>No more than one (1) instances of resource management issues creating a | All personnel proposed by the contractor were assigned to the project. Some personnel were substituted by equally qualified individuals.<br><br>Informal poor performance feedback on conduct of personnel is provided by the COR but are corrected.<br><br>No more than two (2) instances of resource management | All personnel proposed by the contractor were assigned to the project. Some personnel were substituted by equally qualified individuals.<br><br>Formal letter of poor performance feedback on conduct of personnel is provided by the COR but are corrected.<br><br>No more than three (3) instances of resource management | All personnel proposed by the contractor were assigned to the project. Some personnel were substituted by lesser qualified individuals.<br><br>Written request from USACE requesting removal of assigned personnel for poor performance or notification of poor performance is provided by the COR and is not corrected.<br><br>More than three (3) instances of resource management |

| Performance Standard | Excellent | Very Good | Satisfactory | Marginal | Unsatisfactory |
|---|---|---|---|---|---|
| | the activity. | negative impact to the activity. | issues creating a negative impact to the activity. | issues creating a negative impact to the activity. | issues creating a negative impact to the activity. |
| **Performance Category: Stakeholder Involvement** | | | | | |
| **Stakeholder Concurrence** | Contractor applies innovative approaches regarding stakeholder and public involvement activities. | Contractor applies approaches or a combination of approaches that enhances public involvement activities that benefit the project compared to basic required activities. | Contractor applies minimum requirements for stakeholder and public involvement. | Contractor application or misapplication of stakeholder and public involvement activities potentially has a negative impact on project decisions. | Contractor application or misapplication of stakeholder and public involvement activities created a negative impact on project schedule, decisions, and or relationships. |
| **Performance Category: Safety** | | | | | |
| **Safety** | No significant safety deficiencies are reported during QA inspection of fieldwork. No lost time accidents or injuries are recorded during the fieldwork. | No more than one (1) serious safety deficiencies are reported during QA inspection of fieldwork. If any serious safety deficiency is noted during the project, appropriate investigation, corrective action, implementation, and written verification of the corrective action are provided to the Army. No lost time accidents or injuries are recorded during | No more than two (2) serious safety deficiencies are reported during QA inspection of fieldwork. If any serious safety deficiency is noted during the project, appropriate investigation, corrective action, implementation, and written verification of the corrective action are provided to the Army. No lost time accidents or injuries are | No more than three (3) serious safety deficiencies are reported during QA inspection of fieldwork. If any serious safety deficiency is noted during the project, appropriate investigation, corrective action, implementation, and written verification of the corrective action are provided to the Army. No more than one lost time accident or injury is recorded during | More than three (3) serious safety deficiencies are reported during QA inspection of field activities, or a serious safety deficiency is reported but not properly investigated and corrected, or two or more lost time accidents or injuries is recorded during field activities |

| Performance Standard | Excellent | Very Good | Satisfactory | Marginal | Unsatisfactory |
|---|---|---|---|---|---|
| | | the fieldwork. | recorded during the fieldwork. | the fieldwork. | |
| **Performance Category: Cost Control (Not Applicable for Firm Fixed Price Contracts)** | | | | | |
| NA | NA | NA | NA | NA | NA |

The following guidelines are provided for issuing ratings that are subjective in nature, these ratings will be supported by the weight of evidence documented during the government's surveillance efforts:

Excellent: Performance meets contractual requirements and exceeds many to the Government's benefit. The contractual performance of the element or sub-element being assessed was accomplished with few minor problems for which corrective actions taken by the Contractor were highly effective.

Very Good: Performance meets contractual requirements and exceeds some to the Government's benefit. The contractual performance of the element or sub-element being assessed was accomplished with some minor problems for which corrective actions taken by the Contractor were effective.

Satisfactory: Performance meets contractual requirements. The contractual performance of the element or sub-element contains some minor problems for which corrective actions taken by the Contractor appear or were satisfactory.

Marginal: Performance does not meet all contractual requirements. The contractual performance of the element or sub-element being assessed reflects a serious problem for which the Contractor has not yet identified corrective actions. The Contractor's proposed actions appear only marginally effective or were not fully implemented.

Unsatisfactory: Performance does not meet most contractual requirements and recovery is not likely in a timely manner. The contractual performance of the element or sub-element contains serious problems for which the Contractor's corrective actions appear or were ineffective.

3.4 Performance Assessment Process. If a deliverable is rated as being unsatisfactory for quality or stakeholder concurrence at the time that the approved PWS deadline for the milestone expires, the Contractor will automatically receive an unsatisfactory rating for Schedule, unless there is an Army approved delay that extends the PWS performance objective.

3.4.1 Army Approved Delays. At the discretion of the COR, the performance standard of Schedule may be waived in accordance with the criteria outlined in Table B-2. Army-Approved Delays will be tracked by the contractor and reported to the COR monthly.

3.4.2 Stakeholder Concurrence Waiver. At the discretion of the COR, the performance standard of Stakeholder Concurrence may be waived in accordance with the criteria outlined in Table B-2.

3.4.3 Overall Rating.

- An Excellent rating will be achieved only if more than 50% of the 21 milestone ratings (as shown on Table B-2) for the task order are Excellent, with no unacceptable ratings allowed.

- A Very Good rating will be achieved only if more than 50% of the 21 milestone ratings (as shown on Table B-2) for the task order are Very Good or Excellent, with no unacceptable ratings allowed.

- An Acceptable rating will be achieved only if more than 50% of the 21 milestone ratings (as shown on Table B-2) for the task order are Acceptable or better, with no more than 1 of the 21 milestone ratings rated as unacceptable.

- A Marginal rating will be achieved if the criteria for an overall Acceptable rating are not fully met and there are no more than 2 of the 21 milestones rated as unacceptable.

- An Unsatisfactory rating will be achieved if there are more than 2 of the 21 milestone rated as unacceptable.

Table B-2 - Evaluation Standards Table (Key Milestones/Deliverables)

| | **Milestone/Deliverable*** | **Quality** | **Schedule** | **Resource Management** | **Stakeholder Concurrence** | **Safety** |
|---|---|---|---|---|---|---|
| 1 | FINAL Project Management Plan | X | X | X | | |
| 2 | DRAFT FINAL RI UFP-QAPP for Training Range Areas 1 and 2 (CASWA-001-R-01) | X | | | | |
| 3 | FINAL RI UFP-QAPP for Training Range Areas 20 and 21 (CASWA-001-R-01) | X | | X | X | |
| 4 | Geophysical Data Submittal | X | | X | | X |
| 5 | Dig Sheets Data Submittal | X | | X | | X |
| 6 | MC Submission and Scrap Disposal Records Submission | X | | X | | X |
| 7 | DRAFT FINAL RI Report for Training Range Areas 1 and 2 (CASWA-001-R-01) | X | | | | |
| 8 | FINAL RI Report for Training Range Areas 1 and 2 (CASWA-001-R-01) | X | X | X | X | |
| | TOTAL NUMBER OF RATINGS: | 8 | 2 | 6 | 2 | 3 |

* Includes Key Milestones and Key Deliverables from PWS and Payment Milestones from Contractor PMP, June 2012.

4.0 Surveillance Methodology. Table B-3 and Table B-4 summarize the surveillance activities planned for the QASP. The surveillance methods listed below will be used in the administration of this QASP.

4.1 100% Inspection. All project milestones and deliverables will be evaluated through 100% inspection by onsite inspection or document review. The USACE Project Manager will document performance for each completed milestone or deliverable prior to payment, as described in Section 5.0.

4.2 Periodic Inspection. At the USACE Project Manager’s discretion, periodic inspections will be conducted to evaluate progress toward key milestones and deliverables. This will include QA Safety Inspections by a government representative during any fieldwork. The USACE Project Manager may also complete a periodic progress inspection if he/she believes that deficiencies exist that must be addressed prior to milestone or deliverable completion. While corrective action or re-performance will be required if necessary, the Contractor will not be financially penalized for unacceptable performance recorded in periodic progress reports, provided that final performance evaluation of the milestone or deliverable is deemed acceptable.

4.3 Customer Feedback: Contractor performance feedback will be obtained through periodic inquiries by the USACE Project Manager with project stakeholders. The purpose of these inquiries would be to supplement the other forms of evaluation and to also provide the Contractor with constructive criticism and/or recognition for the project deliverables or milestones completed. Customer feedback received will be thoroughly validated to ensure it relates to the requirements of the PWS and will be used in a prudent manner by the COR. Customer feedback will also be solicited in the form of a concurrence letter by the Contractor from appropriate stakeholders (see Table B-2 stakeholder footnotes) for key deliverables.

Table B-3 - Surveillance Activities Table (Key Milestones/Deliverables)

| Milestone | Indicator | Evaluation Standard | Performance Measure | Monitoring Method | Documentation |
|---|---|---|---|---|---|
| COR acceptance of DRAFT FINAL deliverables. | COR acceptance of DRAFT FINAL Documents. | Quality | Army Review of Deliverable | 100% Inspection | USACE Project Manager completion of QAMF, email, letters, customer surveys |
| COR acceptance of FINAL deliverables. | COR acceptance of Final Documents. | Quality<br><br>Resource Management<br><br>Schedule<br><br>Stakeholder Concurrence | Army Review of Deliverable<br><br>Number of incidences regarding contractor personnel/qualifications and/or incidences of task management<br><br>Milestone per (where applicable) PWS<br><br>Resolution of all stakeholder comments. | 100% Inspection<br><br>Periodic Inspection<br><br>Compare to PWS Metric<br><br>Customer Feedback | USACE Project Manager completion of QAMF, email, letters, customer surveys |
| COR acceptance of Data Submittals. | COR acceptance of Data Submittals. | Quality<br><br>Resource Management<br><br>Safety | Army Review of Deliverable<br><br>Number of incidences regarding contractor personnel/qualifications and/or incidences of task management<br><br>Number of Safety deficiencies or incidents | 100% Inspection<br><br>Periodic Inspection<br><br>Periodic Inspection | USACE Project Manager completion of QAMF, email, letters, customer surveys |

Notes:

These key milestones are identified/tied to payment milestones. The "Army" includes stakeholders from the Installation, AEC, and USACE.

* Includes Key Milestones and Key Deliverables from PWS and Payment Milestones from LATA-Matrix PMP, June 2010.

Table B-4 - Surveillance Activities Table (Interim Milestones/Deliverables)

| **Milestone** | **Indicator** | **Evaluation Standard** | **Performance Measure** | **Monitoring Method** | **Documentation** |
|---|---|---|---|---|---|
| Status Reports, Meeting Minute, Memos, Worksheets, and Annual Updates | COR Acceptance of Status Reports, Meeting Minutes, Memos, Worksheets & Annual Updates | NA | Army Review of Deliverable | 100% Inspection | COR Acceptance |
| Milestone Presentations | COR Acceptance of Status Report | NA | Army Review of Deliverable | 100% Inspection | COR Acceptance |

5.0 Surveillance Documentation.

5.1 Quality Assurance Monitoring. The COR or designee will use a Quality Assurance Monitoring Form (QAMF) (the PDT should include a sample QAMF as Attachment A) to record evaluation of the Contractor's performance for each payment milestone or final deliverable in accordance with the methodology described in Section 3.0 and Section 4.0. The USACE Project Manager must substantiate, through narratives on the form, all superior and unacceptable ratings. Performance at the acceptable level is expected from the Contractor. At a minimum, the evaluation form will indicate actual and scheduled delivery times and number of reviews required to achieve the final product. The USACE Project Manager will forward copies of all completed QAMFs to the USACE COR within 7 days of performing the inspection. The USACE Project Manager will forward all completed quality assurance monitoring forms to the AEC ERM and Contractor within 14 days.

5.2 Technical Quality Assurance Monitoring. In general, all work will be evaluated in terms of how well the requirements of the task order are satisfied, the extent to which the work performed follows the approach found in the contractor's technical proposal and/or implements the decision of Technical Project Planning, and clarity of documentation. At the discretion of the COR or the Contracting Officer or Specialist, other government officials approved by the Contracting Officer or Specialist may be asked to evaluate a particular deliverable or set of deliverables. The results of all Technical Quality Assurance Monitoring will be documented using a Technical Review Form. Technical Quality Assurance Monitoring Documentation will document technical criteria evaluated. The PDT should include example forms in Attachment B that will be updated as needed. Example Technical Quality Assurance Monitoring forms are included in Appendix C of EM 200-1-15.

5.3 Corrective Action Process. When a key milestone/deliverable receives a marginal or unacceptable rating, the Contractor will explain, within 15 days, in writing to both the USACE COR and USACE Project Manager why performance was marginal or unacceptable, how performance will be returned to acceptable levels, and how recurrence of the problem will be prevented in the future. The Contractor shall use the corrective action request (CAR) form as part of this process (the PDT should include a sample CAR as Attachment C). The USACE COR will review the proposed corrective action with the AEC ERM and USACE Project Manager, and Installation POC, as necessary, to determine if it will be accepted.

5.4 KO and COR Roles in Surveillance Process. The USACE Project Manager will provide the COR and KO with copies of all completed QAMFs. When appropriate, the COR and/or KO may investigate further to determine if all the facts and circumstances surrounding the event were considered in the USACE Project Manager opinions outlined on the form. The COR and/or KO will immediately discuss any unacceptable rating with the Contractor's Program Manager to assure that corrective action is promptly initiated. At the end of the contract performance period, the USACE Project Manager will prepare a written report for the COR and KO summarizing the overall results of the surveillance of the Contractor's performance during the contract. This report will become part of the formal QA documentation. The USACE Project Manager will maintain a complete QA file. This file will contain copies of all performance evaluation forms and any other related documentation. The USACE Project Manager will forward these records through the COR and to the KO at termination or completion of the contract.

6.0 Payment.

6.1 Acceptable Performance. The Contractor will also be required to perform a milestone presentation per the PWS. At the discretion of the COR, these milestone presentations may be conducted as part of the next regularly scheduled Project Meeting. Full payment for a milestone will be provided upon verification of overall acceptable performance as indicated on the QAMF. The contractor should provide an invoice to the USACE Project Manager after receipt of the QAMF from the USACE indicating acceptable performance. If a QAMF is not provided to the Contractor within 14 days of completion of the milestone the Contractor will submit an invoice.

6.2 Unsatisfactory Performance. If a milestone or deliverable receives an unsatisfactory rating for either the quality or stakeholder concurrence performance standard, re-performance is required until the deliverable receives an acceptable rating. This re-performance is required regardless of cost or schedule constraints that may result from the unsatisfactory performance, unless the USACE Project Manager waives the timeliness or stakeholder concurrence requirement for that specific deliverable or the KO has opted to terminate the contract.

QASP Approval:

________________________________________

Marie Curie, P.E. Date

Contracting Officer's Representative

ATTACHMENT A

EXAMPLE QUALITY ASSURANCE MONITORING FORM

| | |
|---|---|
| Date: | Installation: |
| Milestone/Deliverable/Standard: | |
| Survey Period: | |
| Method of Surveillance: | |
| Author's Name and Phone Number: | |
| Evaluation of Contractor's Performance: | |
| Corrective Action Required: Yes _______ | No: ______ |
| Narrative Discussion of Contractor's Performance During Survey Period: | |

ATTACHMENT B

Example Technical Quality Assurance Monitoring Forms are included in Appendix C of EM 200-1-15.

ATTACHMENT C1

EXAMPLE CORRECTIVE ACTION REQUEST FORM

| | |
|---|---|
| Date: | Location: |
| Installation | Survey Period: |
| Milestone(s)/Deliverable Standards(s): | |
| Author's Name and Phone Number: | |
| Description of the Failure/Deficiency that Precipitated the Corrective Action: | |
| Description of the Criterion that the Failure/Deficiency was Evaluated Against: | |
| Personnel Involved in Identification of the Failure/Deficiency: | |
| Personnel Involved in Determination of the Appropriate Corrective Action: | |
| Personnel Involved in Approval of the Corrective Action: | |
| Personnel Involved in Implementation of the Corrective Action: | |
| Description of the Corrective Action that was Required: | |
| Date/Time of Implementation of the Corrective Action: | |
| Follow Up Information to Prevent Recurrence of Failure/ Deficiency (i.e., Need For Revision of Procedures or Specifications): | |
| Personnel Responsible for Follow-Up Work: | |
| Planned Date for Follow Up Surveillance: | |
| Other Notes: | |

ATTACHMENT C2

EXAMPLE CORRECTION ACTION REQUEST FORM

| **CORRECTIVE ACTION REQUEST** | **REPORT NO.** *(1,2,3, etc.for the T.O.)* |
|---|---|
| 1. USACE Representative: | 2. Date: |
| 3. Project Name/Location: | 4. Weather conditions: |
| 5. Contractor: | |
| 6. Contract#: | 7. T.O. #: |

8. Distributed to: (*District PM, Design Center or Remedial Action District TM, Contractor)*

9. Response Due Date: (*Based on type of nonconformance IF REQUIRED)*

10. Type of activity conducted: *(Include types of inspections/audits conducted, operations observed, etc.)*

11. Additional Discipline-Specific Checklist Attached? (circle one) Yes No
If yes, name checklist(s) (e.g., DGM data processing checklist):

12. Results and observations:

13. Nonconformance Type (circle one): Critical Major Minor NA

14. USACE Representative Signature:

15. Contractor Representative Signature (Indicating Receipt of QAR):

**(The Contractor will provide the following information to the Contract Specialist by the "Response Due" date above. Please contact the Contracting Officer Representative or Project Manager if you have any questions)**

16. Contractor Response as to Cause, Actions Taken to Correct Current Condition and to Prevent Recurrence: (Cite applicable QC procedures or changes in plans, procedures, or practices)

17. Contractor Representative Signature/Title/Date Signed: (Form must be signed before returning)

18. Government Evaluation: (Acceptance, partial acceptance, etc.)

19. Government Actions: (Reduced payment, cure notice, show cause, other)

20. Close Out

| | Name | Title | Signature | Date (YYYMMDD) |
|---|---|---|---|---|
| Contractor Notified | | | | |
| USACE PDT Representative | | | | |
| Contracting Officer or COR | | | | |

Instructions:

Block 1: Name of USACE representative conducting the QA Activity.

Block 2: Date QA Activity completed.

Block 3: Project Name and location, i.e., “Camp Swampy (MRS-02), Smithville, Alaska”.

Block 4: Weather conditions, if applicable.

Block 5: Contractor and/or subcontractor executing the work.

Block 6: Contract number.

Block 7: Task Order number.

Block 8: List by name all official recipients of the QAR.

Block 9: Enter the date that the contractor is to respond, if applicable.

Block 10: List all QA related activities, inspections, audits, operations observed, etc.

Block 11: Denote whether or not additional discipline-specific checklists are attached and if so, which ones are attached.

Block 12: Describe results and observations of each QA activity conducted. Attach discipline-specific checklists/documentation used.

Block 13: Circle type of deficiency, if any, observed. Use contract specific definitions if available, or use the following general definitions:

-Critical; A nonconformance that is likely to result in hazardous or unsafe conditions for individuals using, maintaining, or depending upon the supplies or services; or is likely to prevent performance of a vital agency mission.

-Major: A nonconformance, other than critical, that is likely to result in failure of the supplies or services, or to materially reduce the usability of the supplies or services for their intended purpose.

-Minor: means a nonconformance that is not likely to materially reduce the usability of the supplies or services for their intended purpose, or is a departure from established standards having little bearing on the effective use or operation of the supplies or services.

Block 14: QA representative signature.

Block 15: Contractor representative signature. Signature does not indicate concurrence with stated findings, only that contractor has received the report.

Block 16: Contractor indicates action(s) taken to determine cause of nonconformance, action taken to correct immediate nonconformance, and action taken to prevent a recurrence of the nonconformance. Include dates of actions taken and a schedule for completion of planned actions.

Block 17: Contractor representative signature, title and date.

Block 18: Indicate government acceptance of contractors actions to correct identified nonconformance.

Block 19: Indicate negative government actions taken as a result of the nonconformance.

Block 20: Signature of contractor, PDT representative and contracting officer or COR indicating close out for all nonconformances indicated.

# APPENDIX C

## Sample Discipline-Specific Quality Assurance Reports

### DGM Data Submittals

**Draft DIGITAL GEOPHYSICAL MAPPING QUALITY ASSURANCE FORM *(DATA SUBMITTAL)***

**U.S. Army Corps of Engineers District**
***[Camp Swampy, AL, RI, ABC UXO]***
**Lot ID:**

Recommend Payment: Yes [ ] No [X]
QA Reviewer: John Smith
Date: 1/23/2012

| | *Pass* | *Fail* | *See Comments* | *Field Observation* | *N/A* |
|---|---|---|---|---|---|
| 1) Submittal Ontime | [ ] | [X] | [ ] | [ ] | [ ] |
| 2) Submittal Complete (raw/processed data files (mapping & QC), maps, field data sheets, updated Access DB (includes QC results, target selection tables, etc.) | [X] | [ ] | [ ] | [ ] | [ ] |
| 3) Performance Requirements Results (all results documented & failures have RCAs: Static Repeatability, Along line measurement spacing, Speed, Coverage, Dynamic Detection & Positioning Repeatability, Geodetic Equipment Functionality/internal consistency/accuracy) | [ ] | [X] | [ ] | [ ] | [ ] |
| 4) Periodic Recalculation of Performance Requirements (include details in comments section) | | | | | |
| (a) Static Repeatability | [X] | [ ] | [ ] | [ ] | [ ] |
| (b) Along Line Measurement Spacing | [X] | [ ] | [ ] | [ ] | [ ] |
| (c) Speed | [X] | [ ] | [ ] | [ ] | [ ] |
| (d) Coverage | [X] | [ ] | [ ] | [ ] | [ ] |
| (e) Dynamic Detection Repeatability | [X] | [ ] | [ ] | [ ] | [ ] |
| (f) Dynamic Positioning Repeatability | [X] | [ ] | [ ] | [ ] | [ ] |
| (g) Geodetic Functionality | [X] | [ ] | [ ] | [ ] | [ ] |
| (h) Geodetic Internal Consistency | [X] | [ ] | [ ] | [ ] | [ ] |
| 5) Review of Maps/Gridded data (Assess Potential Field) (visual check: background levelling, striping, latency, noise, in particular view seed items for dynamic detection repeatability) | [X] | [ ] | [ ] | [ ] | [ ] |
| 6) Target Selection (following selection criteria for anomaly & dig lists, each single anomaly has one unique ID, cultural features noted/not selected to dig, no gridding artifacts, reporting of anomaly characteristics accurate) | [X] | [ ] | [ ] | [ ] | [ ] |
| 7) Root Cause Analyses/Non-conformances Reported & Accepted | [ ] | [ ] | [X] | [ ] | [ ] |
| 8) Any additional field observations/QA (add notes below) | [ ] | [ ] | [X] | [ ] | [ ] |

*Quality Assurance Comments:*

*Corrective Action Report issued for not meeting the DGM blind seeding requirements. Response is due 2 weeks from the date on this QAR.*

QA Lot: Grids 73, 123, 124, 128, 212, 219, 287

# Anomaly Resolution

**Draft DIGITAL GEOPHYSICAL MAPPING QUALITY ASSURANCE FORM** ***(Anomaly Resolution)***

**U.S. Army Corps of Engineers District**
***[Camp Swampy, AL, RI, ABC UXO]***
**Lot ID:**

Recommend Payment: Yes [X] No [ ]
QA Reviewer: John Smith
Date: 1/23/2012

| | *Pass* | *Fail* | *See Comments* | *Field Observation* | *N/A* |
|---|---|---|---|---|---|
| 1) Submittal Ontime/complete (updated Access Tables) | X | | | | |
| 2) Reacquisition Results (offset within allowable distance, reacquisition amplitude field data sheets, updated Access DB (includes >=80% original, No contacts with original values >x, etc.) | X | | | | |
| 3) Acceptance Sampling (no unresolved anomalies in sample) (post-dig amplitude < criteria or fully documented rationale) | X | | | | |
| 4) Root Cause Analyses/Non-conformances Reported & Accepted | X | | | | |
| 5) Any additional field observations/QA (add notes below) | X | | | | |

*Quality Assurance Comments:*

All performance metrics met and data submittal submitted on time.

QA Lot: Grids 1, 2, and 3

# SAMPLE FIELD AUDIT – FORM BASED ON EM 200-1-6

Field Oversight Checklist – General Procedures

Project Name: Former State AFB

Address: City, State

Facility Contact & Phone Number: Bob, Smith, (111) 222-3333

Sampling Team Leader: John Brown

Affiliation: ABC MMRP Contractor, Inc.

Address & Phone Number: Street, City, State, Zip, (444) 555-6666

Sampling Personnel: John Brown

Field Oversight Personnel: Jill Lively

Affiliation: CEHNC

Date(s) of Oversight: 26-27 June 2003

Checklist section(s) completed for this overview:

1 X 2___3 X 4___5___6___7___8___

KEY:

| | |
|---|---|
| 1 General Procedures | 2 Groundwater Sampling |
| 3 Soil & Sediment Sampling | 4 Surface Water Sampling |
| 5 Waste Sampling | 6 Storm Water Sampling |
| 7 Air Sampling | 8 Potable Water Sampling |

1) Type of samples collected? Soil

Comments: None

2) Were sampling locations properly selected? Yes X No___

Comments: Contractor used GPS to relocate samples from previous sampling event that were high; the remainder of the samples were randomly placed.

3) Were sampling locations adequately documented in a bound field logbook using indelible ink?
Yes_____ No X

Comments: UFP-QAPP had no field log requirements specified. However, log is minimal – typically limited to time collected and sample identification. One sample was back-entered and another was missing from logbook when reviewed. Some intervals were 6" (one auger bucket); others were 18" (3 auger buckets). Depth of sample (and size of interval) should be noted clearly for all samples. No information was recorded about soil conditions, which varied from stiff clay to topsoil to sand and from very dark brown (almost black) to very light brown (sand).

4) Were photos taken and photolog maintained? Yes____ No X

Comments: I did take some site photographs.

5) What field instruments were used during this study? GPS

6) Were field instruments properly calibrated and calibrations recorded in a bound field logbook? Yes _____ No_____ N/A X

Comments: GPS was factory calibrated.

7) Was sampling equipment properly wrapped and protected from possible contamination prior to sample collection? Yes X No______

Comments: None

8) Was sampling equipment constructed of Teflon®, polyethylene, glass, or stainless steel? Yes X No_____

Comments: Encore samplers were also used.

9) Were samples collected in proper order? (least suspected contamination to most contaminated?)
Yes_____ No X

Comments: Samples from berm (hottest, most accessible) were collected first. They were collected in numeric order, for the most part.

10) Were clean disposable latex or vinyl gloves worn during sampling? Yes X No_____

Comments: None

11) Were gloves changed before each sample? Yes X No____

Comments: None

12) Was any equipment field cleaned? Yes X No____

Comments: None

13) Type of equipment cleaned? Bowls, spoons, auger bucket

14) Were proper cleaning procedures used? Yes _X_ No____

Comments: Liquinox + water, water, ASTM Type II DI water

15) Were equipment rinse blanks collected after field cleaning? Yes _X_ No____

Comments: Only 1 VOC vial collected. Typically, 3 are collected for aqueous VOC samples.

16) Were proper sample containers used for samples? Yes _X_ No____

Comments: Bottle certifications were appropriate.

17) Were split samples offered to the regulatory agency representative? Yes _____ No____ N/A _X

Comments: None

18) Was a receipt for samples form given to regulatory agency representative? Yes____ No___ N/A _X

Comments: None

19) Were any duplicate samples collected? Yes _X_ No____

Comments: Two duplicates collected; 93R-5 and 93R-16

20) Were samples properly field preserved? Yes _X_ No ____

Comments: Majority required samples to be cooled to 4ºC; all samples were placed in a cooler with ice; rinsate metals sample was collected in a bottle pre-preserved with $HNO_3$; rinsate VOCs sample was collected in a bottle pre-preserved with HCl.

21) Were preservative blanks utilized? Yes ____ No _X

Comments: None

22) Were field and/or trip blanks utilized? Yes _X_ No____

Comments: Trip blanks only.

23) Were samples adequately identified with labels or tags? Yes _X No____

Comments: None

24) Were coolers sealed with custody seals after collection? Yes _X_ No____

Comments: Custody seals were taped at my request.

25) Were security measures taken to insure custody of the samples after collection? Yes _X_ No____

Comments: Samples were either physically with the sampler, locked in the vehicle, or locked in the sampler's hotel room.

26) Were chain-of-custody and receipt for sample forms properly completed? Yes _X_ No____

Comments: CoC in 2nd cooler was a photocopy of the first COC. This is not good practice – each cooler should have a CoC that indicates what is really in it. If the photocopy method is used in the future, the CoC and copy should be annotated to show which containers are associated with which cooler. Contractor is not currently using any sort of request for analysis form. The CoC referred the laboratory to the quote. Recommended that they consider some sort of analysis request in the cooler that states method specifics rather than referring to a quote that may not be readily available to login personnel.

27) Were any samples shipped to laboratory? Yes _X_ No____

Comments Samples were held overnight; WP requires that samples be shipped each day, but CEHNC rep agreed to hold samples in order to complete all sampling in one day.

28) If yes to No. 27, were samples properly packed? Yes____ No _X_

Comments:

SVOC bottles were placed horizontally not vertically

VOC cooler was compressed significantly (probably had too much ice in too small a cooler)

Soil jars were not individually wrapped; they were put back in shipping box inside the cooler

Sampler only had one temperature blank; so only one cooler got a temperature blank

Sampler purchased plain packing tape, not fiber tape as specified in WP

Coolers did not have "This side up" or "Fragile" labels, although one was marked already

Ice was placed in cooler in its original packaging (8-10# bag) inside a garbage bag, rather than in Ziploc bags that could be placed around the samples

29) What safety monitoring equipment, protection, and procedures were used prior to and during sampling? Safety briefing conducted; no monitoring performed (or required); PPE (gloves) were used.

30) Was safety monitoring equipment properly calibrated and were calibrations recorded in a bound field logbook? Yes ____ No ____ N/A _X

Comments: None

## Example Field Oversight Checklist – Soil and Sediment Sampling

1) Type of samples collected? Soil (surface and subsurface)

2) General description of samples? Discrete samples, variety of soil types and colors, ranged from stiff clay to sand to topsoil

3) How many samples were collected? 20 (+ QC samples, which included 2 MS/MSDs, 2 duplicates, and 1 rinsate)

4) Were background and/or control samples collected? Yes ____ No X

Comments: None

5) Were representative samples collected? Yes X No____

Comments: Many samples were stiff clay – sampler made a good effort to break them up and mix them up.

6) Were grab or composite samples collected? Grab

7) Were composite samples areal or vertical? N/A

8) How many aliquots were taken for the composite sample? N/A

9) What procedures and equipment were used to collect samples? Spoon; Encore sampler (VOCs); hand auger (at depth)

10) Were samples thoroughly mixed prior to putting them into the sample containers? Yes X No ____

Comments: Not mixed for Encore samplers; else, see #5 on page 5.

11) Were samples properly placed into sample containers? Yes X No____

Comments ____________________________

12) Were samples chilled with water and iced immediately after collection? Yes X No ___

13) For what analyses were the samples collected? VOCs, SVOCs, metals, explosives

14) If samples were split, what were the sample/station numbers for these? N/A

15) Was a drilling rig, backhoe, etc., used to collect soil samples? Yes ____ No X

Comments: None

16) What was done with the soil cuttings from the drill rig or backhoe? N/A

17) Were the cuttings collected for proper disposal, or containerized until characterized? Yes___ No X

Comments: Cuttings from hand auger were replaced in hole.

18) Were the drilling rig, back hoe, etc., properly cleaned prior to arriving on site? Yes _X_ No____

Comments: None

19) What was the condition of the drilling and sampling equipment when it arrived on site? (cleanliness, leaking jacks, peeling paint) Satisfactory

20) Was a decontamination area located where the cleaning activities would not cross-contaminate clean and/or drying equipment? Yes _X_ No____

Comments: Decon was performed in plastic tubs that were taken from location to location in vehicle.

21) Was clean equipment properly wrapped and stored in a clean area? Yes _X_ No____

Comments: None

22) Was the drilling rig(s) properly cleaned between well borings? Yes ____ No____ N/A _X

Comments: None

22) Were the cleaning and decontamination procedures conducted in accordance with the project plans? Yes _X_ No____

Comments: None

23) Other comments or observations.

Sampler only had one hand auger bucket, so he couldn't use a clean bucket for the sampling interval at depth. He collected as he went due to refusal concerns (prior direction had been to sample at 5' or refusal for samples at depth). It would probably have been difficult to have had a new bowl/auger at the correct interval if he reached refusal, which he did several times. Recommended that he bring more than one bucket next time.

GPS accuracy is a real problem. Current requirement is to measure to sample locations to 1' accuracy, but that requirement post-dates this WP, which doesn't specify GPS accuracy for sampling. The GPS used for this event (and the initial event) was accurate to 20'. Reacquisition of exact sample locations is unlikely – sampler was unable to relocate one point he had staked the day before.

Sampler was not well prepared. He was unable to meet several minor WP requirements due to lack of appropriate supplies (i.e., temperature blanks, cooler labels, fiber tape, individual sample wrapping, and VOC vials) and did not attempt to correct these problems in the field when they were noted. He did acquire rinsate bottles from a local laboratory because their laboratory did not ship any. Coolers used were those provided by the laboratories, and they were probably too small to contain the samples and an appropriate amount of ice.

Jim Smith, Contractor Chemist, called on 3 July 2003 to inform HNC that samples were received at 9 ºC based on IR gun measurement.

# APPENDIX D

## Chemical/Physical Properties of Munitions Constituents

### Table D-1: Chemical/Physical Properties of Primary Explosives

| Compound | Chemical Formula | Abbreviation | CAS Number | Molecular Weight | Melting Point (°C) | Boiling Point (°C) | Vapor Pressure (mm Hg) | Water Solubility (mg/L) | Log $K_{ow}$ | $K_{oc}$ | Henry's Law constant (atm-$m^3$/mole) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lead azide | $N_6$-Pb | LA | 13424-46-9 | 291.24 | 190 (decomp)[a] | 350 (explodes)[a] | U [d] | 230 @ 18°C[a] | 1.47 (est.)[g] | U [d] | U [d] |
| Mercury fulminate | $C_2$-Hg-$N_2$-$O_2$ | - | 628-86-4 | 284.62 | 210 (explodes)[f] | NA [d] | 0.000612 @ 25°C (est.)[b] | 100 @ 15.5°C[a] | -4.83 (est.)[b] | 11.1 (est.)[b] | U [d] |
| Diazodinitrophenol | $C_6$-$H_3$-$N_4$-$O_5$ | DDNP | 4682-03-5 | 211.11 | 230.43 (est.)[b] | 538.16 (est.)[b] | $1.95 \times 10^{-12}$ @ 25°C (est.)[b] | 630.5 @ 25°C (est.)[b] | 2.09 (est.)[b] | NA [d, e] | $2.86 \times 10^{-9}$ (est.)[b] |
| Lead styphnate | $C_6$-H-$N_3$-$O_8$-Pb | - | 15245-44-0 | 468.3 | 235 (decomp)[a] | 260-310 (explodes)[c] | $2.65 \times 10^{-9}$ @ 25°C (est.)[b] | Practically insoluble in water [a] | 1.06 (est.)[b] | 3010 (est.)[b] | $3.58 \times 10^{-11}$ (est.)[b] |
| Tetracene | $C_{18}$-$H_{12}$ | - | 92-24-0 | 228.30 | 357[b] | 399 (est.)[b] | $2.49 \times 10^{-9}$ [b] | 0.00151 @ 25°C [b] | 5.76 [b] | $6.46 \times 10^{5}$ [b] | $5.01 \times 10^{-6}$ (est.)[b] |
| Potassium dinitrobenzofuroxane | K-$C_6$-$H_4$-$N_4$-$O_6$ | KDNBF | 42994-94-5 | 265.20 | 210 (explodes)[c] | NA [d] | U [d] | 2,450 @ 30°C[c] | 0.99 (est.)[g] | U [d] | U [d] |
| Lead mononitroresorcinate | $C_6$-$H_5$-N-$O_4$-Pb | LMNR | 51317-24-9 | 364.32 | U [d] | U [d] | U [d] | U [d] | 1.31 (est.)[g] | U [d] | U [d] |

Note:
°C = degrees Celsius
atm-$m^3$/mol = atmostpher meters cubed per mol
CAS = Chemical Abstract Summary
Hg = mercury
Kow = Octanol-Water Partition Coefficient
Koc = Organic Carbon Partition Coefficient
mg/L = milligrams per liter
mm = millimeters
[a] Hazardous Substances Data Bank (HSDB), available at http://toxnet.nlm.nih.gov/, retrieved in March-September 2012
[b] USEPA, 2011. Estimation Programs Interface (EPI) Suite™ for Microsoft® Windows, v 4.10. United States Environmental Protection Agency, Washington, DC, USA.
[c] US Army Materiel Command, 1971, Engineering Design Handbook: Explosives Series – Properties of Explosives of Military Interest, AMC Pamphlet (AMCP) 706-177, January 1971; Online version available at: http://www.knovel.com/web/portal/browse/display?_EXT_KNOVEL_DISPLAY_bookid=3846&VerticalID=0
[d] U – Unavailable; NA – Not applicable
[e] This chemical is a Quaternary Ammonium Compound (QAC). Adsorption of QACs seem to occur mainly by an ion-exchange mechanism and depends on cation-exchange capacity of the sorbent and variety of other parameters. [b]
[f] USARDEC, 1960. Encyclopedia of Explosives and Related Items, PATR 2700, U.S. Army Research and Development Command; TACOM, ARDEC; Warheads, Energetics and Combat Support Center; Picatinny Arsenal; New Jersey, USA.
[g] Chemspider (http://www.chemspider.com/), predicted properties **generated using ChemAxon (http://www.chemicalize.org/)**

Table D-2: Chemical/Physical Properties of Secondary Explosives, Co-Contaminants, and Breakdown Products

| Compound | Chemical Formula | Abbreviation | CAS Number | Molecular Weight | Melting Point (°C) | Boiling Point (°C) | Vapor Pressure (mm Hg) | Water Solubility (mg/L) | Log $K_{ow}$ | $K_{oc}$ | Henry's Law constant (atm-$m^3$/mole) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Aliphatic Nitrate Esters** | | | | | | | | | | | |
| 1,2,4-Butanetriol trinitrate | $C_4$-$H_7$-$N_3$-$O_9$ | BTN | 6659-60-5 | 241.12 | 60.3 (est.)[b] | 297 (est.)[b] | 0.00106 @ 25°C (est.)[b] | 515 @ 25°C (est.)[b] | 2.00 (est.)[b] | 54.4 (est.)[b] | 3.37 x $10^{-9}$ (est.)[b] |
| Diethyleneglycol dinitrate | $C_4$-$H_8$-$N_2$-$O_7$ | DEGN | 693-21-0 | 196.116 | -11.3[a] | 161[a] | 5.9 x $10^{-3}$ @ 25°C [a] | 3.9 x $10^{3}$ @ 25°C [a] | 0.98[a] | 32 (est.)[a] | 3.9 x $10^{-7}$ (est.)[a] |
| Nitrocellulose | $C_{12}$-$H_{21}$-N-$O_{13}$ | NC | 9004-70-0 | 387.30 | 262 (est.)[b] | 606 (est.)[b] | 1.41 x $10^{-17}$ @ 25°C (est.)[b] | Immiscible [a] | -4.56 (est.)[b] | 0.0020 3 (est.)[b] | 3.29x$10^{-23}$ (est.)[b] |
| Nitroglycerin | $C_3$-$H_5$-$N_3$-$O_9$ | NG | 55-63-0 | 227.09 | 2.8 and 13.5[a] | 218 (explodes)[a] | 2.0x$10^{-4}$ @ 20°C[a] | 1,800 @ 25°C[a] | 1.62[a] | 180 (est.)[a] | 4.3x$10^{-8}$ (est.)[a] |
| Nitrostarch | $C_{12}$-$H_{12}$-$(NO_2)_8$-$O_{10}$ | NS | 9056-38-6 | 684.26 | U [g] | U [g] | U [g] | U [g] | U [g] | U [g] | U [g] |
| Pentaerythritol tetranitrate | $C_5$-$H_8$-$N_4$-$O_{12}$ | PETN | 78-11-5 | 316.14 | 140.5[a] | 205-215 (explodes)[a] | 1.36x$10^{-7}$ @ 25°C [a] | 43 @ 25°C [a] | 2.38 (est.)[a] | 650 (est.)[a] | 1.32x$10^{-9}$ (est.)[a] |
| Triethylene glycoldinitrate | $C_6$-$H_{12}$-$N_2$-$O_8$ | TEGN | 111-22-8 | 240.17 | 65.8 (est.)[b] | 298 (est.)[b] | 0.000907 @ 25°C (est.)[b] | 6,600 @ 25°C [b] | 0.6224 (est.)[b] | 26.2 (est.)[b] | 1.71 x $10^{-10}$ (est.)[b] |
| 1,1,1-Trimethylolethane trinitrate | $C_5$-$H_9$-$N_3$-$O_9$ | TMETN | 3032-55-1 | 255.14 | 77.2 (est.)[b] | 306 (est.)[b] | 0.000453 @ 25°C (est.)[b] | 516 @ 19°C [b] | 2.46 (est.)[b] | 331 (est.)[b] | 4.47 x $10^{-9}$ (est.)[b] |
| **Nitramines** | | | | | | | | | | | |
| Octahydro-1, 3, 5, 7-tetranitro-1,3,5,7-tetrazocine | $C_4$-$H_8$-$N_8$-$O_8$ | HMX | 2691-41-0 | 296.15 | 281[a] | 280 (decomp)[a] | 2.41x$10^{-8}$ @ 25°C[a] | 5 @ 25°C[b] | 0.16[b] | 18.9 (est.)[b] | 8.67x$10^{-10}$ (est.) [a] |
| Hexahydro-1,3,5-trinitro-1,3,5-triazine | $C_3$-$H_6$-$N_6$-$O_6$ | RDX | 121-82-4 | 222.12 | 205.5[b] | 353 (est.)[b] | 4.10x$10^{-9}$ @ 20°C [b] | 60 @ 25°C[c] | 0.87[b] | 51.7 (est.)[b] | 2.0x$10^{-11}$ [c] |
| Ethylenediamine dinitrate | $C_2$-$H_{10}$-$N_4$-$O_6$ | EDDN | 20829-66-7 | 186.124 | U [g] | 372 (est.)[h] | 4.59 x $10^{-7}$ @ 25°C (est.)[h] | U [g] | -1.42 (est.)[i] | U [g] | U [g] |
| Ethylenedinitramine | $C_2$-$H_6$-$N_4$-$O_4$ | Haleite | 505-71-5 | 150.09 | 67 (est.)[b] | 266 (est.)[b] | 0.00464 @ 25°C (est.)[b] | 2,300 @ 20°C[b] | -1.80 (est.)[b] | 40.6 (est.)[b] | 3.82 x $10^{-11}$ (est.)[b] |
| Nitroguanidine | C-$H_4$-$N_4$-$O_2$ | NQ | 556-88-7 | 104.07 | 239 (decomp)[a] | NA [g] | 1.43x$10^{-11}$ @ 25°C[a] | 4.4x$10^{3}$ @ 25°C[a] | -0.89 [a] | 12 (est.)[a] | 4.45x$10^{-16}$ (est.)[a] |
| 2,4,6-Trinitrophenyl-methylnitramine | $C_7$-$H_5$-$N_5$-$O_8$ | Tetryl | 479-45-8 | 287.14 | 130-132 | 187 (explodes)[a] | 1.2x$10^{-7}$ @ 25°C (est.)[a] | 74 @ 25°C[a] | 1.64 (est.)[a] | 2,100 (est.)[a] | 2.7x10-9 (est.)[a] |
| **Nitroaromatics** | | | | | | | | | | | |

| Compound | Chemical Formula | Abbreviation | CAS Number | Molecular Weight | Melting Point (°C) | Boiling Point (°C) | Vapor Pressure (mm Hg) | Water Solubility (mg/L) | Log $K_{ow}$ | $K_{oc}$ | Henry's Law constant (atm-$m^3$/mole) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,4,6-Trinitrophenol (Picric Acid) | $C_6$-$H_3$-$N_3$-$O_7$ | PA | 88-89-1 | 229.10 | 122-123[a] | 300 (explodes)[a] | 7.5x$10^{-7}$ @ 25°C[a] | 1.27x$10^{4}$ @ 25°C[a] | 1.44[a] | 180 (est.)[a] | 1.7x$10^{-8}$[a] |
| Ammonium Picrate | $C_6$-$H_6$-$N_4$-$O_7$ | AP | 131-74-8 | 246.13 | decomp [a] | NA [g] | 3.37 x $10^{-11}$ @ 25°C (est.)[b] | 10 @ 20°C[a] | -1.40 (est.)[b] | 5363 (est.)[b] | 2.94 x $10^{-22}$ (est.)[b] |
| 1,3-Diamino-2,4,6-trinitrobenzene | $C_6$-$H_5$-$N_5$-$O_6$ | DATB | 1630-08-6 | 243.14 | 182 (est.)[b] | 439 (est.)[b] | 2.15 x $10^{-8}$ @ 25°C (est.)[b] | 5.24 x $10^{4}$ @ 25°C (est.)[b] | -0.36 (est.)[b] | 424 (est.)[b] | 2.43 x $10^{-13}$ (est.)[b] |
| 2,2',4,4',6,6'-hexanitroazobenzene | $C_{12}$-$H_4$-$N_8$-$O_{12}$ | HNAB | 19159-68-3 | 452.21 | 274 (est.)[b] | 635 (est.)[b] | 1.62 x $10^{-14}$ @ 25°C (est.)[b] | 0.146 @ 25°C (est.)[b] | 4.17 (est.)[b] | 5.16x $10^{6}$ (est.)[b] | 5.55 x $10^{-20}$ (est.)[b] |
| 1,3,5-Triamino-2,4,6-trinitrobenzene | $C_6$-$H_6$-$N_6$-$O_6$ | TATB | 3058-38-6 | 258.15 | 350[b] | 481 (est.)[b] | 1.58 x $10^{-11}$ @ 25°C (est.)[b] | 2.63 x $10^{5}$ @ 25°C (est.)[b] | -1.28 (est.)[b] | 707 (est.)[b] | 8.60 x $10^{-17}$ (est.)[b] |
| 2,4,6-Trinitrotoluene | $C_7$-$H_5$-$N_3$-$O_6$ | TNT | 118-96-7 | 227.13 | 80.1[a] | 240 (explodes)[a] | 8.02x$10^{-6}$ @ 25°C[a] | 115 @ 23°C[a] | 1.60 [a] | 1,600 [a] | 2.1x$10^{-8}$ (est.)[a] |
| **Other Secondary Explosives** | | | | | | | | | | | |
| Ammonium Nitrate | H4-N2-O3 | - | 6484-52-2 | 80.06 | 169.7[a] | 200-260 (decomp)[a] | 49.8 @ 25°C (est.)[h] | 2,130 @ 25°C[a] | 0.03 (est.)[i] | U [g] | U [g] |
| **Nitroaromatic Breakdown Products/Co-Contaminants** | | | | | | | | | | | |
| 1,3,5-Trinitrobenzene | $C_6$-$H_3$-$N_3$-$O_6$ | 1,3,5-TNB | 99-35-4 | 213.11 | 121.5[a] | 315[a] | 6.44x$10^{-6}$ @ 25°C[a] | 278 @ 15°C[a] | 1.18[a] | 104 (est.)[a] | 6.49x$10^{-9}$[a] |
| 1,3-Dinitrobenzene | $C_6$-$H_4$-$N_2$-$O_4$ | 1,3-DNB | 99-65-0 | 168.11 | 89-90[a] | 291[b] | 2x$10^{-4}$ @ 25°C[a] | 533 @ 25°C[a] | 1.49[a] | 150[a] | 4.9X$10^{-8}$[a] |
| 2,4-Diamino-6-nitrotoluene | $C_7$-$H_9$-$N_3$-$O_2$ | 2,4-DANT | 6629-29-4 | 167.17 | 121 (est.)[b] | 339 (est.)[b] | 2.7x$10^{-5}$ @ 25°C (est.)[b] | 2.1x$10^{4}$ @ 25°C (est.)[b] | 0.55 (est.)[b] | 25.4 (est.)[b] | 2.93x$10^{-12}$ (est.)[b] |
| 2,6-Diamino-4-nitrotoluene | $C_7$-$H_9$-$N_3$-$O_2$ | 2,6-DANT | 59229-75-3 | 167.17 | 121 (est.)[b] | 339 (est.)[b] | 2.7x$10^{-5}$ @ 25°C (est.)[b] | 2.1x$10^{4}$ @ 25°C (est.)[b] | 0.55 (est.)[b] | 25.4 (est.)[b] | 2.93x$10^{-12}$ (est.)[b] |
| 2,4-Dinitrotoluene | $C_7$-$H_6$-$N_2$-$O_4$ | 2,4-DNT | 121-14-2 | 182.14 | 71[a] | 300[a] | 1.47x$10^{-4}$ @ 22°C[a] | 200 @ 25°C[b] | 1.98[a] | 360[a] | 5.4x$10^{-8}$[b] |
| 2,6-Dinitrotoluene | $C_7$-$H_6$-$N_2$-$O_4$ | 2,6-DNT | 606-20-2 | 182.14 | 66[a] | 285[a] | 5.67x$10^{-4}$ @ 25°C[a] | 208 @ 25°C[d] | 2.10[a] | 19-72[a] | 7.5x$10^{-7}$[c] |
| 2-Amino-4,6-dinitrotoluene | $C_7$-H-$_7$-$N_3$-$O_4$ | 2-Am-DNT | 35572-78-2 | 197.15 | 174.5[b] | 342[e] | 3.33x$10^{-6}$ @ 25°C (est.)[b] | 1223@ 25°C (est.)[b] | 1.84 (est.)[b] | 229 (est.)[b] | 3.27x$10^{-11}$ (est.)[b] |
| 4-Amino-2,6-dinitrotoluene | $C_7$-H-$_7$-$N_3$-$O_4$ | 4-Am-DNT | 19406-51-0 | 197.15 | 171[b] | 352 (est.)[b] | 3.65x$10^{-6}$ @ 25°C (est.)[b] | 1223@ 25°C (est.)[b] | 1.84 (est.)[b] | 229 (est.)[b] | 3.27x$10^{-11}$ (est.)[b] |
| 2-Nitrotoluene (o-Nitrotoluene) | $C_7$-$H_7$-N-$O_2$ | 2-NT | 88-72-2 | 137.14 | -10.6/ -4.1[d] | 225[d] | 0.1 @ 20°C [d] | 652 @ 30°C[d] | 2.30[b] | 261 (est.)[b] | 1.25x$10^{-5}$[b] |

| Compound | Chemical Formula | Abbreviation | CAS Number | Molecular Weight | Melting Point (°C) | Boiling Point (°C) | Vapor Pressure (mm Hg) | Water Solubility (mg/L) | Log $K_{ow}$ | $K_{oc}$ | Henry's Law constant (atm-$m^3$/mole) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3-Nitrotoluene (m-Nitrotoluene) | $C_7$-$H_7$-N-$O_2$ | 3-NT | 99-08-1 | 137.14 | 15.5[d] | 231[d] | 0.1 @ 20°C[d] | 498 @ 30°C[d] | 2.45[b] | 510 (est.)[a] | 9.3X10-6[a] |
| 4-Nitrotoluene (p-Nitrotoluene) | $C_7$-$H_7$-N-$O_2$ | 4-NT | 99-99-0 | 137.14 | 51.6[b] | 238.3[b] | $1.57 \times 10^{-2}$ @ 25°C[b] | 2100[c] | 2.37[b] | 285 (est.)[b] | $5.63 \times 10^{-6}$[b] |
| 3,5-Dinitroaniline | $C_6$-$H_5$-$N_3$-$O_4$ | 3,5-DNA | 618-87-1 | 183.12 | 163[f] | 340 (est.)[b] | $8.54 \times 10^{-6}$ @ 25°C (est.)[b] | 1290 @ 25°C (est.)[f] | 1.89[b] | 355[b] | $2.96 \times 10^{-11}$ (est.)[b] |
| Nitrobenzene | $C_6$-$H_5$-N-$O_2$ | NB | 98-95-3 | 123.11 | 5.7[b] | 210.8[b] | $2.45 \times 10^{-1}$ @ 25°C[b] | 2090@ 25°C[b] | 1.85[b] | 87[b] | $2.4 \times 10^{-5}$[c] |
| **Nitramine Breakdown Products** | | | | | | | | | | | |
| Hexahydro-1-nitroso-3,5-dinitro-1,3,5-triazine | $C_3$-$H_6$-$N_6$-$O_5$ | MNX | 5755-27-1 | 206.12 | 145 (est.)[b] | 372 (est.)[b] | $5.37 \times 10^{-6}$ @ 25°C (est.)[b] | 2.1 $\times 10^5$@ 25°C (est.)[b] | -0.84 (est.)[b] | 5.86 (est.)[b] | $4.07 \times 10^{-8}$ (est.)[b] |
| Hexahydro-1,3-dinitroso-5-nitro-1,3,5-triazine | $C_3$-$H_6$-$N_6$-$O_4$ | DNX | 80251-29-2 | 190.12 | 150 (est.)[b] | 390(est.)[b] | $1.81 \times 10^{-6}$ @ 25°C (est.)[b] | $1 \times 10^6$ (est.)[b] | -1.66 (est.)[b] | 1.25 (est.)[b] | $2.62 \times 10^{-8}$ (est.)[b] |
| Hexahydro-1,3,5-trinitroso-1,3,5-triazine | $C_3$-$H_6$-$N_6$-$O_3$ | TNX | 13980-04-6 | 174.12 | 146 (est.)[b] | 408 (est.)[b] | $7.75 \times 10^{-7}$ @ 25°C (est.)[b] | $1 \times 10^6$@ 25°C (est.)[b] | -1.78 (est.)[b] | 0.645 (est.)[b] | $1.69 \times 10^{-8}$ (est.)[b] |

[a] HSDB, available at http://toxnet.nlm.nih.gov/, retrieved in March-September 2012

[b] USEPA, 2011. Estimation Programs Interface (EPI) Suite™ for Microsoft® Windows, v 4.10. United States Environmental Protection Agency, Washington, DC, USA.

[c] USAPHC, 2010. Reference Document 230, Methodology for Determining Chemical Exposure Guidelines for Deployed Military Personnel, June 2010.

[d] Verschueren, Karel (2009). Handbook of Environmental Data on Organic Chemicals, Volumes 1-4 (5th Edition). John Wiley & Sons. Online version available at: http://www.knovel.com/web/portal/browse/display?_EXT_KNOVEL_DISPLAY_bookid=2437&VerticalID=0

[e] Yaws, Carl L. (2008). Yaws' Handbook of Physical Properties for Hydrocarbons and Chemicals. Knovel. Online version available at: http://www.knovel.com/web/portal/browse/display?_EXT_KNOVEL_DISPLAY_bookid=2147&VerticalID=0

[f] SRC Physical Properties database (PHYSPROP), available at http://www.srcinc.com/what-we-do/databaseforms.aspx?id=386, retrieved in July 2012

[g] U – Unavailable; NA – Not applicable

[h] Chemspider (http://www.chemspider.com/), predicted properties **generated using the ACD/Labs' ACD/PhysChem Suite (**http://www.acdlabs.com/products/pc_admet/physchem/physchemsuite/), retrieved in September 2012.

[i] Chemspider (http://www.chemspider.com/), predicted properties **generated using ChemAxon (**http://www.chemicalize.org/**)**

Table D-3: Chemical/Physical Properties of Chemical Agents and Agent Breakdown Products

| Common Name | Chemical Formula | Chemical Name | Abbreviation | CAS Number | Molecular Weight | Melting Point (°C) | Boiling Point (°C) | Vapor Pressure (mm Hg) | Water Solubility (mg/L) | Log $K_{ow}$ | $K_{oc}$ | Henry's Law constant (atm-$m^3$/mole) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Blister Agents** | | | | | | | | | | | | |
| Distilled Mustard | $C_4$-$H_8$-$Cl_2$-S | Bis(2-Chloroethyl)-Sulfide | HD | 505-60-2 | 159.08[a] | 13-14[a] | 215-217[a] | 0.11 @ 25°C[a] | 9.20E+02 [c] | 2.41 (est)[a] | 120[a] | 2.10E-05[c] |
| Ethyldichloro-arsine | $C_2$-$H_5$-As-$Cl_2$ | --- | ED | 598-14-1 | 174.89[a] | -65[a] | 156 (decomposes)[a] | 2.29 @ 21.5°C[a] | Rxts with water[a] | 2.34 (est)[b] | 60.7 (est)[b] | 7.60X10-3 (est)[b] |
| Lewisite | $C_2$-$H_2$-As-$Cl_3$ | Dichloro(2-Chlorovinyl)-Arsine | L | 541-25-3 | 207.32[a] | 0.1[a] | 190 (decomposes)[a] | 0.58 @ 25 °C[a] | 500[a] | 2.56 (est)[b] | 143[a] | 3.2X10-4[a] |
| Methyldichloro-arsine | C-$H_3$-As-$Cl_2$ | --- | MD | 593-89-5 | 160.86 | -55[j] | 133[j] | 7.76 @ 20°C[j] | Rxts with water | 1.85 (est)[b] | 32 (est)[b] | 6.41x10-3 (est)[b] |
| Nitrogen Mustard (HN-1) | $C_6$-$H_{13}$-$Cl_2$-N | Ethylbis(2-Chloroethyl)-Amine | HN-1 | 538-07-8 | 170.08[a] | -34[a] | 194 (decomposes)[a] | 0.25 @ 25°C[a] | 160 @ 25 C[a] | 2.02 (est)[a] | 360[a] | 3.36X10-4[a] |
| Nitrogen Mustard (HN-2) | $C_5$-$H_{11}$-$Cl_2$-N | Mechlorethamine; N,N-Bis(2-Chloroethyl) Methylamine | HN-2 | 51-75-2 | 156.06[a] | -60[a] | 87 deg C @ 18 mm Hg[a] | 0.17 @ 25°C[a] | 12000 @ 25 C[b] | 0.91[a] | 23 (est)[b] | 8.5X10-8 (est)[a] |
| Nitrogen Mustard (HN-3) | $C_6$-$H_{12}$-$Cl_3$-N | Tris(2-Chloroethyl) Amine | HN-3 | 555-77-1 | 204.53[a] | -4[a] | 230-235 (decomposes)[a] | 0.011 @ 25°C[a] | 160 @ 25 C[a] | 2.27 (est)[a] | 672[a] | 1.85X10-5 (est)[a] |
| Phenyldichloro-arsine | $C_6$-$H_5$-As-$Cl_2$ | --- | PD | 696-28-6 | 222.93[a] | -20[a] | 255[a] | 0.113 @ 25°C[a] | Rxts with water[a] | NA | 820[a] | 3.0X10-5 (est)[a] |
| Phosgene Oxime | C-H-$Cl_2$-N-O | --- | CX | 1794-86-1 | 113.9[a] | 39-40[a] | 128[a] | 13 @ 40°C (liquid)[a] | 25000[a] | 0.73 (est)[a] | 68[a] | 5.5X10-7[a] |
| **Blister Agent Breakdown Products** | | | | | | | | | | | | |
| 1,4-Dithiane | $C_4$-$H_8$-$S_2$ | --- | --- | 505-29-3 | 120.23[c] | 112.3[a] | 115.6 deg C at 60 mm Hg[a] | 0.80 @ 25°C[a] | 3000[a] | 0.77[a] | 63[a] | 4.2X10-5[a] |
| 1,4-Oxathiane | $C_4$-$H_8$-O-S | 1,4-Thioxane | | 15980-15-1 | 104.17[d] | -28 (est)[b] | 147[a] | 4.61[d] | 3.99E+04 [d] | 0.53[d] | 19.59[b] | 5.38E-06[d] |
| 2-Chlorovinyl Arsenous Acid | $C_2$-$H_4$-As-CI-$O_2$ | --- | CVAA | 85090-33-1 | 170.427 | NA | NA | NA | NA | NA | NA | NA |
| 2-Chlorovinyl Arsenous Oxide | $C_2$-$H_2$-As-Cl-O | Lewisite Oxide | CVAO | 3088-37-7 | 152.41[b] | 18 (est)[b] | 120.5 (est)[b] | 15.3 @ 25°C (est)[b] | 13000 (est)[b] | 1.94 (est)[b] | 72 (est)[b] | 0.001874 (est)[b] |

| Common Name | Chemical Formula | Chemical Name | Abbreviation | CAS Number | Molecular Weight | Melting Point (°C) | Boiling Point (°C) | Vapor Pressure (mm Hg) | Water Solubility (mg/L) | Log $K_{ow}$ | $K_{oc}$ | Henry's Law constant (atm-m$^3$/mole) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ethyldiethanol-amine | $C_6$-$H_{15}$-N-$O_2$ | --- | --- | 139-87-7 | 133.189[a] | -50[a] | 247[a] | 2.45X10-3 @ 25°C (est)[a] | 1000000 (miscible)[a] | -1.01 (est)[a] | 1[a] | 1.14X10-10 (est)[a] |
| Thiodiglycol | $C_4$-$H_{10}$-$O_2$-S | --- | TDG | 111-48-8 | 122.18[c] | -10.2[a] | 282[a] | 0.00323 @ 25°C[a] | Miscible[a] | -0.63[a] | 11[a] | 1.9X10-9[a] |
| Triethanolamine | $C_6$-$H_{15}$-N-O | --- | TEA | 102-71-6 | 149.19[a] | 20.5[a] | 335.4[a] | 3.59X10-6 @ 25°C[a] | Miscible[a] | -1.00[a] | 7[a] | 7.05X10-13[a] |
| Diethanolamine | $C_4$-$H_{11}$-N-$O_2$ | --- | DEA | 111-42-2 | 105.14[a] | 28[a] | 268.8[a] | 1.4X10-4 @ 25°C[a] | Miscible[a] | -1.43 (est)[a] | 4[a] | 3.9X10-11[a] |
| **Blood Agents** | | | | | | | | | | | | |
| Arsine | As-$H_3$ | --- | SA | 7784-42-1 | 77.95[c] | -116[a] | -62.5[a] | 11,000 @ 20°C[a] | 28[a] | NA | NA | NA |
| Cyanogen Chloride | Cl-C-N | --- | CK | 506-77-4 | 61.48[c] | -6.55[a] | 13[a] | 1.23X10+3 @ 25°C[a] | 27.5[a] | -0.38 (est)[b] | 4.67 (est)[b] | 5.00E-03[c] |
| Hydrogen Cyanide | H-C-N | --- | AC | 74-90-8 | 27.03[c] | -13.4[a] | 25.6[a] | 742 @ 25°C[a] | 1.00E+06[c] | -0.25[a] | NA | 1.30E-04[c] |
| **Choking Agents** | | | | | | | | | | | | |
| Chlorine | $Cl_2$ | --- | --- | 7782-50-5 | 70.91[c] | -101[a] | -34.04[a] | 5.83X10+3 @ 25°C[a] | 6300[a] | NA | NA | 0.0117[a] |
| Chloropicrin | C-$Cl_3$-N-$O_2$ | Trichloronitro-methane | PS | 76-06-2 | 164.38[a] | -64[a] | 112 deg C at 757 mm Hg[a] | 24 @ 25°C[a] | 1.62E10+3[a] | 2.09[a] | 81[a] | 2.05X10-3[a] |
| Diphosgene | $C_2$-$Cl_4$-O | Trichloro-methyl Chloroformate | DP | 503-38-8 | 197.83[a] | -57[a] | 128[a] | 10 @ 20°C[a] | 2389 (est)[b] | 1.49 (est)[b] | 5.972 (est)[b] | 0.000103 (est)[b] |
| Phosgene | C-$Cl_2$-O | Carbonyl Chloride | CG | 75-44-5 | 98.92[c] | -118[a] | 8.2[a] | 1420 @ 25°C[a] | 475100[b] | -0.71 (est)[b] | 2.2[a] | 1.7X10-2 @ 24.85 deg C[a] |
| **Chemical Agent Decontaminant** | | | | | | | | | | | | |
| Acetylene Tetrachloride | $C_2$-$H_2$-$Cl_4$ | 1,1,2,2-Tetrachloroethane | --- | 79-34-5 | 167.85[a] | -43.8[a] | 146.5[a] | 4.62 @ 25°C[a] | 2900[a] | 2.39[a] | 79[a] | 3.67X10-4[a] |
| **Nerve Agents** | | | | | | | | | | | | |
| Cyclosarin | $C_7$-$H_{14}$-F-$O_2$-P | Cyclohexyl Methyl-phosphono-fluoridate | GF | 329-99-7 | 180.16[c] | -30[a] | 239[a] | 0.044 @ 20°C[a] | 3700[a] | 1.60 (est)[a] | 42 (est)[a] | 2.8X10$^{-6}$[a] |

| Common Name | Chemical Formula | Chemical Name | Abbreviation | CAS Number | Molecular Weight | Melting Point (°C) | Boiling Point (°C) | Vapor Pressure (mm Hg) | Water Solubility (mg/L) | Log $K_{ow}$ | $K_{oc}$ | Henry's Law constant (atm-$m^3$/mole) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VX | $C_{11}$-$H_{26}$-N-$O_2$-P-S | o-Ethyl S-(2-diisopropyl-aminoethyl) Methyl-phosphono-thiolate | --- | 50782-69-9 | 267.37[c] | <-51[a] | 298[a] | 0.0007 @ 25°C[a] | 30000[c] | 2.09[a] | 330[a] | 3.5X$10^{-9}$[c] |
| Sarin | $C_4$-$H_{10}$-F-$O_2$-P | Isopropyl Methyl-phosphono-fluoridate | GB | 107-44-8 | 140.09[c] | -57[a] | 147[a] | 2.86 @ 25°C[a] | 1000000 (miscible)[a] | 0.3[a] | 35[a] | 5.3X$10^{-7}$[c] |
| Soman | $C_7$-$H_{16}$-F-$O_2$-P | Pinacolyl Methyl-phosphono-fluoridate | GD | 96-64-0 | 182.18[c] | -42[a] | 167[a] | 0.4 @ 25°C[a] | 21000[c] | 1.778[a] | 221[a] | 4.6X$10^{-6}$[c] |
| Tabun | $C_5$-$H_{11}$-$N_2$-$O_2$-P | Dimethyl-amido-ethoxy-phosphoryl cyanide | GA | 77-81-6 | 162.13[c] | -50[a] | 240[a] | 0.07 @ 25°C[a] | 98000[c] | 0.38[a] | 38[a] | 1.5X$10^{-7}$[c] |
| **Nerve Agent Breakdown Products** | | | | | | | | | | | | |
| Diisopropyl methyl phosphonate | $C_7$-$H_{17}$-$O_3$-P | --- | DIMP | 1445-75-6 | 180.18[c] | <25[b] | 121.05 @ 10 mm Hg[a] | 0.28 @ 25 °C[a] | 1500[a] | 1.03[a] | 87[a] | 4.4X$10^{-5}$[c] |
| Dimethyl methyl phosphonate | $C_3$-$H_9$-$O_3$-P | --- | DMMP | 756-79-6 | 124.08[c] | <50[a] | 181[a] | 0.962 @ 25°C[a] | 1000000[b] | -0.61[a] | 11[a] | 1.25X$10^{-6}$[a] |
| EA 2192 | $C_9$-$H_{22}$-N-$O_2$-P-S | Diisopropyl-amino-ethyl Methyl Thiolo-phosphonate, S-(2-Dilsopropyl-aminoethyl) Methyl-phosphono-thioic Acid | --- | 73207-98-4 | 239.32[b] | 58 (est)[b] | 339 (est)[b] | 0.00000514 @ 25°C (est)[b] | 13990 (est)[b] | 0.96a[f] | 79.4 | 4.38X$10^{-12}$ (est)[b] |
| Ethyl methylphosphonic acid | $C_3$-$H_9$-$O_3$-P | --- | EMPA | 1832-53-7 | 124.08[b] | -8 (est)[b] | 222 (est)[b] | 0.019 @ 25°C (est)[b] | 180000[c] | -0.15 (est)[b] | 5 (est)[b] | 5.18X$10^{-9}$ (est)[b] |
| Isopropyl methyl phosphonic acid | $C_4$-$H_{11}$-P-$0_3$ | --- | IMPA | 1832-54-8 | 138.10[c] | -8 (est)[b] | 230 (est)[b] | 0.0119 @ 25°C (est)[b] | 48000[c] | 0.27 (est)[b] | 8 (est)[b] | 6.88X$10^{-9}$ (est)[b] |
| Methylphosphonic Acid | C-$H_5$-$O_3$-P | --- | MPA | 993-13-5 | 96.02[c] | 108.5[a] | Decomposes[a] | 0.000327 @ 25°C (est)[b] | >20000[a] | -0.70 (est)[a] | 1 (est)[a] | 1.22X$10^{-11}$ (est)[b] |
| Pinacolyl methylphosphonic acid | $C_7$-$H_{17}$-$0_3$-P | --- | PMPA | 616-52-4 | 180.19[b] | 20 (est)[b] | 265 (est)[b] | 0.00124 @ 25°C (est)[b] | 2231 (est)[b] | 1.63 (est)[b] | 33 (est)[b] | 1.61x$10^{-8}$ (est)[b] |

| Common Name | Chemical Formula | Chemical Name | Abbreviation | CAS Number | Molecular Weight | Melting Point (°C) | Boiling Point (°C) | Vapor Pressure (mm Hg) | Water Solubility (mg/L) | Log $K_{ow}$ | $K_{oc}$ | Henry's Law constant (atm-$m^3$/mole) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Incapacitating Agent** | | | | | | | | | | | | |
| 3-Quinuclidinyl benzilate | $C_{21}$-$H_{23}$-N-$O_3$ | 3-(2,2-Diphenyl-2-Hydroxy-ethanoyloxy)-Quinuclidine, aka QNB, EA2277 | BZ | 6581-06-2 | 337.42[a] | 164[a] | 170 deg C (decompo ses)[a] | 2.38X10-10 @ 25°C[a] | 200[a] | 3.01 (est)[a] | 4942 (est)[b] | 5.34X10-[11a] |

Note: NA – Not Available

[a] HSDB, available at http://toxnet.nlm.nih.gov/, retrieved in March 2012

[b] USEPA, 2011. Estimation Programs Interface (EPI) Suite™ for Microsoft® Windows, v 4.10. United States Environmental Protection Agency, Washington, DC, USA.

[c] USAPHC, 2010. Reference Document 230, Methodology for Determining Chemical Exposure Guidelines for Deployed Military Personnel, June 2010.

[d] SRC PHYSPROP, available at http://www.srcinc.com/what-we-do/databaseforms.aspx?id=386, retrieved in March 2012

[e] NIOSH Pocket Guide to Chemical Hazards (NPG), 2010, available at http://www.cdc.gov/niosh/npg/pgintrod.html

[f] Munro et al. The Sources, Fate, and Toxicity of Chemical Warfare Agent Degradation Products. Environmental Health Perspectives, Volume 107, No. 12, December 1999

[g] ToxProfiles, Agency for Toxic Substances and Disease Registry, available at http://www.atsdr.cdc.gov/toxprofiles/index.asp, retrieved in March 2012

[h] Toxicity of Military Smokes and Obscurants, National Academies Press. Volume 1 (1997), Volume 2 (1999) and Volume 3 (1999).

[I] California Office of Environmental Health Hazard Assessment, available at http://oehha.ca.gov/, retrieved in March 2012

[j] Berkeley Database

Table D-4: Chemical/Physical Properties of Riot Agents and Smokes

| Common Name | Chemical Formula | Chemical Name | Abbreviation | CAS Number | Molecular Weight | Melting Point (°C) | Boiling Point (°C) | Vapor Pressure (mm Hg) | Water Solubility (mg/L) | Log $K_{ow}$ | $K_{oc}$ | Henry's Law constant (atm-$m^3$/mole) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Riot Control – Tear Agents** | | | | | | | | | | | | |
| Bromoacetone | $C_3$-$H_5$-Br-O | 1-Bromo-2-Propanone | BA | 598-31-2 | 136.99[a] | -36.5[a] | 137[a] | 90 @ 20°C[d] | 6.96E+04[d] | 0.11[d] | 4 (est)[a] | 5.7X10-6 (est)[a] |
| Bromobenzyl-cyanide | $C_8$-$H_6$-Br-N | Alpha-Bromobenzene-aceto-nitrile, Camite | BBC, CA | 5798-79-8 | 196.05[a] | 29[a] | 242[a] | 0.012 @ 20°C[a] | 678.2 (est)[b] | 1.83 (est)[b] | 286.1[b] | 2.84E-07[b] |
| Chloro-acetophenone | $C_8$-$H_7$-Cl-O | 2-Chloroaceto-phenone, Mace, 2-Chloro-1-Phenylethanone | CN | 532-27-4 | 154.59[c] | 58-59[a] | 244-245[a] | 0.0054 @ 20°C[a] | 470[c] | 1.93 (est)[b] | 90[a] | 3.5X10-6[a] |
| Dibenzox-azepine | $C_{13}$-$H_9$-N-O | Dibenz(b,f)[1,4]Oxazepine | CR | 257-07-8 | 195.22[a] | 73[a] | 321 (est)[b] | 2.2X10-4 @ 25°C (est)[a] | 124 (est)[a] | 3.01 (est)[a] | 1020 (est)[a] | 4.1X10-3[a] |
| o-Chlorobenzalmalonitrile | $C_{10}$-$H_5$-Cl-$N_2$ | O-Chlorobenzylidene Malononitrile | CS | 2698-41-1 | 188.62[a] | 95-96[a] | 310-315[a] | 3.4X10-5 @ 20°C[a] | 51.9[d] | 2.76 (est)[a] | 1700 (est)[a] | 1.0X10-8[a] |
| Oleoresin Capsicum "Pepper Spray" | $C_{18}$-$H_{27}$-N-$O_3$ | Capsaicin (Primary Active Ingredient) | OC | 404-86-4 | 305.462[a] | 65[a] | 210-220 @ 0.01 mm Hg[a] | 1.3X10-8 @ 25°C (est)[a] | 10.3 (est)[a] | 3.04[a] | 1100 (est)[a] | 1.0X10-13[a] |
| **Riot Control – Vomiting Agents** | | | | | | | | | | | | |
| Adamsite | $C_{12}$-$H_9$-As-Cl-N | Phenarsazine Chloride | DM | 578-94-9 | 227.58[a] | 195[a] | 410 (decomposes)[a] | 2x10-13 @ 20°C[a] | 0.65[a] | 4.05 (est)[a] | 5750 (est)[a] | 3.3X10-8[a] |
| Diphenyl-chloroarsine (Clark I) | $C_{12}$-$H_{10}$-As-Cl | --- | DA | 712-48-1 | 264.59[b] | 44[a] | 337[a] | 0.0002 @ 25°C[a] | 2.72[a] | 4.52[a] | 1.53E+04[b] | 0.0000368[a] |
| Diphenyl-cyanoarsine (Clark 2) | $C_{13}$-$H_{10}$-As-N | --- | DC | 23525-22-6 | 255.15[b] | 93 (est)[b] | 376 (est)[b] | 0.00000716 @ 25°C[b] | 18.82[b] | 3.29 (est)[b] | 6274 (est)[b] | 0.0000001277 (est)[b] |
| **Smokes** | | | | | | | | | | | | |
| Chlorosulfonic Acid | Cl-H-$O_3$-S | With Sulfur Trioxide, makes up FS | --- | 7790-94-5 | 116.53[a] | -80[a] | 151-152 @ 755 mm Hg[a] | 0.75 @ 20°C[a] | Rxts with water[a] | NA | NA | NA |
| Hexachloro-ethane | $C_2$-$Cl_6$ | --- | HC | 67-72-1 | 236.74[c] | Sublimes[a] | Sublimes[a] | 0.4 @ 20°C[a] | 41[c] | 4.14[a] | 1,380 to 2,360[a] | 3.90E-03[c] |

| Common Name | Chemical Formula | Chemical Name | Abbreviation | CAS Number | Molecular Weight | Melting Point (°C) | Boiling Point (°C) | Vapor Pressure (mm Hg) | Water Solubility (mg/L) | Log $K_{ow}$ | $K_{oc}$ | Henry's Law constant (atm-$m^3$/mole) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Red Phosphorus | $(P_4)_n$ | Amorphous Phosphorus | RP | 7723-14-0 | 123.9[h] | Sublimes at 416°C[h] | 280.5[k] | 0.03 @ 21°C[i] | negligible in water[h] | NA | NA | NA |
| Silicon Tetrachloride | $Si\text{-}Cl_4$ | --- | --- | 10026-04-7 | 169.90[a] | -70[a] | 59[a] | 236 @ 25°C[a] | Rxts with water[a] | NA | NA | NA |
| Sulfur Trioxide | $S\text{-}O_3$ | With Chlorosulfonic Acid, makes up FS | --- | 7446-11-9 | 80.063[a] | 62.2[a] | Sublimes [a] | 263 @ 25°C (est)[a] | Rxts with water[a] | NA | NA | NA |
| Tin Tetrachloride | $Sn\text{-}Cl_4$ | Stannic Chloride | KJ | 7646-78-8 | 260.52[a] | -33[a] | 114.15[a] | 18 @ 20°C[a] | Rxts with water[a] | NA | NA | NA |
| Titanium Tetrachloride | $Ti\text{-}Cl_4$ | --- | FM | 7550-45-0 | 189.68[c] | -24.1[a] | 136.4[a] | 10 @ 20°C[g] | NA | NA | NA | NA |
| White Phosphorus | $P_4$ | WP aka Molecular Phosphorus; Elemental P (Valence State 0) - CAS# 7723-14-0 | WP | 12185-10-3 | 123.90[a] | 44.1[a] | 280[a] | 0.026 @ 20°C[a] | 3[k] | NA | NA | NA |

Note: NA – Not Available

[a] HSDB, available at http://toxnet.nlm.nih.gov/, retrieved in March 2012

[b] USEPA, 2011. Estimation Programs Interface (EPI) Suite™ for Microsoft® Windows, v 4.10. United States Environmental Protection Agency, Washington, DC, USA.

[c] USAPHC, 2010. Reference Document 230, Methodology for Determining Chemical Exposure Guidelines for Deployed Military Personnel, June 2010.

[d] SRC PHYSPROP, available at http://www.srcinc.com/what-we-do/databaseforms.aspx?id=386, retrieved in March 2012

[e] NIOSH Pocket Guide to Chemical Hazards (NPG), 2010, available at http://www.cdc.gov/niosh/npg/pgintrod.html

[f] Munro et al. The Sources, Fate, and Toxicity of Chemical Warfare Agent Degradation Products. Environmental Health Perspectives, Volume 107, No. 12, December 1999

[g] ToxProfiles, Agency for Toxic Substances and Disease Registry, available at http://www.atsdr.cdc.gov/toxprofiles/index.asp, retrieved in March 2012

[h] Toxicity of Military Smokes and Obscurants, National Academies Press. Volume 1 (1997), Volume 2 (1999) and Volume 3 (1999).

[I] California Office of Environmental Health Hazard Assessment, available at http://oehha.ca.gov/, retrieved in March 2012

# GLOSSARY

## Section I -- Abbreviations

2-Am-DNT............................2-Amino-4,6-Dinitrotoluene
2-NT......................................2-Nitrotoluene
2,4-DNT................................2,4-Dinitrotoluene
2,6-DNT................................2,6-Dinitrotoluene
4-Am-DNT............................4-Amino-2,6-Dinitrotoluene
4-NT......................................4-Nitrotoluene
AAPP ....................................Abbreviated Accident Prevention Plan
AAR......................................After Action Report
ABP.......................................Agent Breakdown Product
AC.........................................Hydrogen Cyanide
ADR......................................Automated Date Review
AEDB-R................................Army Environmental Database-Restoration
AEL.......................................Airborne Exposure Limit
AES.......................................Atomic Emission Spectrometry
AHA......................................Activity Hazard Analysis
AKO......................................Army Knowledge Online
Al...........................................Aluminum
ALARACT............................All Army Activities Message
ALLTEM ..............................All-Time EMI System
AP .........................................Ammonium Picrate
APP.......................................Accident Prevention Plan
ARAR ...................................Applicable or Relevant and Appropriate Requirement
AS .........................................Asbestine Suspension
ASCII....................................American Standard Code for Information Interchange
ASR.......................................Archives Search Report
ATF.......................................Alcohol Tobacco and Firearms
ATSDR .................................Agency for Toxic Substances and Disease Registry
AUV......................................Autonomous Vehicle
AVS.......................................Acid Volatile Sulfides
BA.........................................Bromoacetone
BBC.......................................Bromobenzylcyanide
BERA....................................Baseline Environmental Risk Assessment
bgs.........................................Below Ground Surface
BIP ........................................Blow in Place
BMP......................................Bit Map
BOSS.....................................Buried Object Scanning Sonar
BRA ......................................Baseline Risk Assessment
BRAC....................................Base Realignment and Closure
BUD......................................Berkeley UXO Discriminator
BZ .........................................3-Quinuclidinyl Benzilate
CA.........................................Chemical Agent

CAA ....................................Clean Air Act
CAC ....................................Common Access Card
CADD ..................................Computer-aided Design and Drafting
CAIS ...................................Chemical Agent Identification Set
CAR ....................................Corrective Action Request
CAS.....................................Chemical Abstracts Service
CD.......................................Compact Disk
CDC ....................................Contained Detonation Chamber
CDFR ..................................Chemical Data Final Report
CDQC ..................................Chemical Data Quality Control
CEES...................................2-Chloroethyl Ethyl Sulfide
CERCLA..............................Comprehensive Environmental Response, Compensation and Liability Act
CFR.....................................Code of Federal Regulations
CG.......................................Phosgene
CK.......................................Cyanogen Chloride
Cl.........................................Chlorine
cm........................................Centimeter
CMUA..................................Concentrated Munitions Use Area
CN.......................................Tear Gas
$CO_2$.......................................Carbon Dioxide
COPC ..................................Chemical of Potential Concern
COTS ...................................Commercial Off the Shelf
CPR.....................................Cardiopulmonary Resuscitation
CQC ....................................Chemical Quality Control
CR .......................................Diphenylcyanoarsine
CRP.....................................Community Relations Plan
CRREL.................................Cold Regions Research Engineering Laboratory
CS........................................o-Chlorobenzalmalonitrile
CSM ....................................Conceptual Site Model
CVAA ..................................Cold Vapor Atomic Absorption
CVAO ..................................Lewisite Oxide
CW.......................................Chemical Weapon
CWA ....................................Chemical Warfare Agent
CWC ....................................Chemical Weapons Convention
CWM....................................Chemical Warfare Materiel
CWM DC.............................Chemical Warfare Materiel Design Center
CX .......................................Center of Expertise
cy.........................................Cubic Yards
CZMA ..................................Coastal Zone Management Act
DA.......................................Department of the Army <u>or</u> Diphenylchloroarsine
DAC.....................................United States Army Defense Ammunition Center
DANC ..................................Decontaminating Agent, Non-Corrosive
DANT ..................................Diaminonitrotoluene
DA PAM ..............................Department of the Army Pamphlet

DASA-ESOH........................Deputy Assistant Secretary of the Army for Environment, Safety, and Occupational Health
DC........................................Design Center <u>or</u> Diphenylcyanoarsine
DDESB .................................Department of Defense Explosives Safety Board
DERP ....................................Defense Environmental Restoration Program
DGM ....................................Digital Geophysical Mapping
DGPS ....................................Differential Global Positioning System
DM ........................................Adamsite
DMM....................................Discarded Military Munitions
DNT ......................................Dinitrotoluene
DNX......................................Hexahydro-1.3-dinitroso-5-nitro-1,3,5-triazine
DoD.......................................Department of Defense
DoDIC...................................Department of Defense Identification Code
DoDM ...................................Department of Defense Manual
DOE ......................................Department of Energy
DOP.......................................Dilution of Precision
DOT ......................................Department of Transportation
DP .........................................Diphosgene
$D_{PE}$ ..........................................Deflection Probable Error
DQCR ...................................Data Quality Control Report
DQO......................................Data Quality Objective
DSSS.....................................Direct Sequence Spread Spectrum
DU.........................................Depleted Uranium
DVD......................................Digital Video Disc
EC .........................................Engineer Circular <u>or</u> Ethyl Centralite
ECBC ....................................Edgewood Chemical Biological Center
ECD.......................................Electron Capture Detector
EDD ......................................Electronic Data Deliverable
EE/CA ...................................Engineering Evaluation / Cost Analysis
EKO ......................................Engineering Knowledge Online
ELAP.....................................Environmental Laboratory Accreditation Program
EM.........................................Engineer Manual or Electromagnetic
EM CX ..................................Environmental and Munitions Center of Expertise
EMI .......................................Electromagnetic Induction
EO .........................................Executive Order
EOD ......................................Explosive Ordnance Disposal
EP..........................................Engineer Pamphlet
EPC .......................................Exposure Point Concentration
EPP........................................Environmental Protection Plan
ER .........................................Engineer Regulation
ERA.......................................Ecological Risk Assessment
ERAGS .................................Ecological Risk Assessment Guidance for Superfund
ERDC....................................Engineering Research and Development Center
ERIS......................................Environmental Restoration Information System
ESTCP...................................Environmental Security Technology Certification Program

FAR........................................Federal Acquisition Regulation
FBR........................................Fluidized Bed Reactor
FDEMI...................................Frequency Domain Electromagnetic Induction
FM..........................................Titanium Tetrachloride
FOA........................................Field Operating Activities
FRMD....................................Formerly Used Defense Site Records Management Database
FS...........................................Feasibility Study or Chlorosulfonic Acid
FUDS.....................................Formerly Used Defense Site
FUDSMIS..............................Formerly Used Defense Site Management Information System
G.............................................Gram
GA..........................................Tabun (Ethyl N, N-dimethylphosphoramidocyanidate)
GAC.......................................Granular Activated Carbon
GB..........................................Sarin
GC..........................................Gas Chromatography
GD..........................................Soman (Pinacolyl methylphosphonofluoridate)
GDS........................................Geospatial Data and System
GF..........................................Cyclosarin
GFAA.....................................Graphite Furnace Atomic Absorption Spectrophotometry
GIS.........................................Geographic Information System
GPO........................................Geophysical Prove-out
GPR........................................Ground Penetrating Radar
GPS........................................Global Positioning System
GSV........................................Geophysical Systems Verification
H.............................................Mustard
HA..........................................Hazard Assessment
HC..........................................Hexachloroethane
HD..........................................Distilled Mustard
HDOP.....................................Horizontal Dilution of Precision
HE..........................................High Explosive
HHE.......................................Health Hazard Evaluation
HHRA....................................Human Health Risk Assessment
HMX......................................Octahydro-1,3,5,7-tetrazocine
HN-1, 2, 3..............................Nitrogen Mustards
HPLC.....................................High Performance Liquid Chromatography
HQAES..................................Headquarters, Army Environmental System
HQUSACE.............................Headquarters, United States Army Corps of Engineers
HRR.......................................Historical Records Review
HTRW....................................Hazardous, Toxic, and Radioactive Waste
HUMMA................................Hawai‘i Undersea Military Munitions Assessment
Hz...........................................Hertz
IAW........................................In Accordance with
ICP.........................................Inductively Coupled Plasma
IDW........................................Investigation-Derived Waste
IGD........................................Interim Guidance Document
IHF.........................................Interim Holding Facility

INS ........................................Inertial Navigation Systems
IS ...........................................Incremental Sample
ISE.........................................Ion Selective Electrode
ISO ........................................Industry Standard Object
ITRC ......................................Interstate Technology Regulatory Council
IVS ........................................Instrument Verification Strip
JPEG ......................................Joint Photographic Experts Group
KJ ...........................................Tin Tetrachloride
KO.........................................Contracting Officer
KPA.......................................Kinetic Phosphorescence Analysis
L ............................................Liters
LC ..........................................Liquid Chromatography
LCS .......................................Laboratory Control Spike
LIDAR ...................................Light Detection and Ranging
LOD .......................................Limit of Detection
LOQ .......................................Limit of Quantitation
LTM .......................................Long-Term Management
LUC.......................................Land Use Control
m ............................................Meters
M2S2.....................................Military Munitions Support Services
Mb..........................................Megabyte
MBES....................................Multibeam Echo Sounder
MC .........................................Munitions Constituents
MD .........................................Munitions Debris
MEC.......................................Munitions and Explosives of Concern
MFD.......................................Maximum Fragmentation Distance
mg/L.......................................Milligrams per Liter
MIDAS...................................Munition Items Disposition Action System
MK2 .......................................Mark 2
mm .........................................Millimeters
MMDC...................................Military Munitions Design Center
MMRP...................................Military Munitions Response Program
MNX ......................................Hexahydro-1-nitroso-3,5-dinitro-1,3,5-triazine
MP..........................................Man-Portable
MPPEH ..................................Material Potentially Presenting an Explosive Hazard
MPV.......................................Man-Portable Vector Sensor
MQO ......................................Measurement Quality Objective
MR .........................................Munitions Response or Molasses Residuum
MRA ......................................Munitions Response Area
MRCSP .................................Munitions Response Chemical Site Plan
MRCSS .................................Munitions Response Chemical Safety Submission
MRESP .................................Munitions Response Explosives Site Plan
MRESS .................................Munitions Response Explosives Safety Submission
MRS.......................................Munitions Response Site
MRSPP..................................Munitions Response Site Prioritization Protocol

MS..........................................Mass Spectrometry or Matrix Spike
ms..........................................Millisecond
mV..........................................MilliVolt
NAGPRA...............................Native American Graves Protection and Repatriation Act
NC..........................................Nitrocellulose
NCMUA................................Non-Concentrated Munitions Use
NCP.......................................National Oil and Hazardous Substances Pollution Contingency Plan
NDAI.....................................No DoD Action Indicated
NDGPS .................................Nationwide Differential Global Positioning System
NEW .....................................Net Explosive Weight
NFA.......................................No Further Action
NG.........................................Nitroglycerine
NIOSH ..................................National Institute of Occupational Safety and Health
NPD.......................................Nitrogen Phosphorous Detector
NPDES..................................National Pollutant Discharge Elimination System
NQ.........................................Nitroquanidine
NRHP....................................National Register of Historic Places
NRL.......................................Naval Research Lab
NSCMP.................................Non-Stockpile Chemical Materiel Program
NSN.......................................National Stock Number
NTCRA.................................Non-Time Critical Removal Action
O&M.....................................Operations and Maintenance
OB.........................................Open Burn
OC.........................................Oleoresin Capsicum
OD.........................................Open Detonation
OESS.....................................Ordnance and Explosives Safety Specialist
ORISE...................................Oak Ridge Institute for Science and Education
OSHA....................................Occupational Safety and Health Administration
PA .........................................Preliminary Assessment
PAH.......................................Polynuclear Aromatic Hydrocarbon
PARCCS...............................Precision, Accuracy, Representativeness, Completeness, Comparability, and Sensitivity
Pb ..........................................Lead
PDOP ....................................Position Dilution of Precision
PDS .......................................Post-Digestion Spike
PDT .......................................Project Delivery Team
PE..........................................Performance Evaluation
PETN.....................................Pentaerylthritol tetranitrate
PLS........................................Professional Land Surveyor
PM.........................................Project Manager
PMP.......................................Project Management Plan
PNNL ....................................Pacific Northwest National Laboratory
PP ..........................................Post Processing
PPE........................................Personal Protective Equipment

PPRTV ....................................Provisional Peer Reviewed Toxicity Value
PQO........................................Project Quality Objective
PRV........................................Post-Remediation Validation
PS ..........................................Chloropicrin
PSP.........................................Physical Security Plan
PWP .......................................Plasticized White Phosphorus
PWS .......................................Performance Work Statement
QA..........................................Quality Assurance
QAPP .....................................Quality Assurance Project Plan
QASP .....................................Quality Assurance Surveillance Plan
QC ..........................................Quality Control
QMS.......................................Quality Management System
QSM.......................................Quality Systems Manual
RA ..........................................Removal Action
RAB .......................................Restoration Advisory Board
RAGS.....................................Risk Assessment Guidance for Superfund
RAIS ......................................Risk Assessment Information System
RAO .......................................Remedial Action Objective
RCRA.....................................Resource Conservation and Recovery Act
RD ..........................................Remedial Design
RDX .......................................Hexahydro-1,3,5-trinitro-1,3,5-triazine
RF...........................................Radio Frequency
RI............................................Remedial Investigation
RLS ........................................Registered Land Surveyor
RmD ......................................Remedial Action
RMS.......................................Root Mean Square
ROE........................................Right of Entry
ROV .......................................Remotely Operated Vehicle
RP...........................................Red Phosphorus
$R_{PE}$ ..........................................Range Probable Error
RTK........................................Real-Time Kinematic
RTS ........................................Robotic Total Station
SA ..........................................Selective Availability or Arsine
SAR........................................Synthetic Aperture Radar or Small Arms Range
SAS ........................................Synthetic Aperture Sonar
Sb ..........................................Antimony
SBP ........................................Sub-Bottom Profiler
SDSFIE ..................................Spatial Data Standards for Facilities, Infrastructure, and the Environment
SEDD .....................................Staged Electronic Data Deliverable
SEM .......................................Simultaneously Extracted Metals
SERDP ...................................Strategic Environmental Research and Development Program
SHPO .....................................State Historical Preservation Office
SI............................................Site Inspection
SIM ........................................Selected Ion Monitoring

SLERA....................................Screening-Level Ecological Risk Assessment
SNR........................................Signal to Noise Ratio
SOP ........................................Standard Operating Procedure
SOW.......................................Statement of Work
SPE.........................................Solid-Phase Extraction
SPME .....................................Solid-Phase Micro-Extraction
SR...........................................Stationary Receivers
SSHP ......................................Site Safety and Health Plan
SSS .........................................Side-Scan Sonar
TBC........................................To Be Considered
TCLP......................................Toxicity Characteristic Leaching Procedures
TCRA .....................................Time Critical Removal Action
TDEMI...................................Time Domain Electromagnetic Induction
TDG .......................................Thiodiglycol
TDOP .....................................Time Dilution of Precision
TEMTADS.............................Time Domain Electromagnetic Multi-Sensor Towed Array Detection System
TH ..........................................Thermite
TH3 ........................................Thermate
TH4 ........................................Thermate
THPO .....................................Tribal Historic Preservation Office
TIFF .......................................Tagged Image File Format
TM..........................................Technical Manual
TNB........................................Trinitrobenzene
TNT........................................Trinitrotoluene
TNX .......................................Hexahydro-1,3,5-trinitroso-1,3,5-triazine
TOI.........................................Target of Interest
TPP.........................................Technical Project Planning
TR ..........................................Technical Report
TRW.......................................Technical Review Workgroup
UFP-QAPP.............................Uniform Federal Policy – Quality Assurance Project Plan
U.S. ........................................United States
USACE ..................................United States Army Corps of Engineers
USAEC ..................................United States Army Environmental Command
USAEHA ...............................United States Army Environmental Hygiene Agency
USAIPH .................................United States Army Institute of Public Health
USAPHC................................United States Army Public Health Command
USATCES..............................United States Army Technical Center for Explosives Safety
USATHAMA.........................United States Army Toxic and Hazardous Materials Agency
USC........................................United States Code
USEPA...................................United States Environmental Protection Agency
USGS .....................................United States Geological Survey
UTM.......................................Universal Transverse Mercator
UV..........................................Ultraviolet
UXO.......................................Unexploded Ordnance

UXOSO..................................Unexploded Ordnance Safety Officer
VDOP.....................................Vertical Dilution of Precision
VSP ........................................Visual Sampling Plan
VX..........................................o-Ethyl S-(2-diisopropylaminoethyl
WAA......................................Wide Area Assessment

WAAS....................................Wide Area Augmentation System
WMP......................................Waste Management Plan
WP..........................................White Phosphorous
WWI.......................................World War I
WWII .....................................World War II
XRF........................................X-Ray Fluorescence
μg/L........................................Micrograms per Liter
μm .........................................Micrometers

## Section II - Terms

Active Installations
Installations under the custody and control of Department of Defense. Includes operating installations, installations in a standby or layaway status, and installations awaiting closure under the Base Realignment and Closure legislation.

Active Range
A military range that is currently in service and is being regularly used for range activities (40 CFR 266.201).

Administrative Record
The body of documents that "forms the basis" for the selection of a particular response at a site. Documents that are included are relevant documents that were relied upon in selecting the response action as well as relevant documents that were considered but were ultimately rejected. Until the Administrative Record is certified, it shall be referred to as the "Administrative Record file."

Agent Breakdown Products (ABPs)
Degradation products of chemical agents; compounds that have been identified that are formed by decomposition, hydrolysis, microbial degradation, oxidation, photolysis, and decontamination. Discussions of ABPs may also include co-contaminants that were impurities formed during manufacture.

Anomaly
Any item that is seen as a subsurface irregularity after geophysical investigation. This irregularity will deviate from the expected subsurface ferrous and non-ferrous material at a site (e.g., pipes, power lines).

Anomaly Avoidance
Techniques employed by explosive ordnance disposal or unexploded ordnance (UXO) personnel on property known or suspected to contain UXO, other munitions that may have experienced abnormal environments (e.g., discarded military munitions), munitions constituents in high enough concentrations to pose an explosive hazard, or chemical agent (CA), regardless of configuration to avoid contact with potential surface or subsurface explosive or CA hazards, to allow entry to the area for the performance of required operations.

Applicable or Relevant and Appropriate Requirements (ARARs)
Applicable requirements are cleanup standards, standards of control, and other substantive environmental protection requirements promulgated under Federal or state environmental law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance found at a Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) site. Relevant and appropriate requirements are cleanup standards that, while not "applicable", address situations sufficiently similar to those encountered at a CERCLA site that their use is well suited to the particular site.

Archives Search Report (ASR)
A detailed investigation to report on past MEC activities conducted on an installation. The principal purpose of the Archives Search is to assemble historical records and available field data, assess potential ordnance presence, and recommend follow-up actions at a Defense Environmental Restoration Program – Formerly Used Defense Sites. There are four general steps in an Archives Search: records search phase, site safety and health plan, site survey, and archives search report including risk assessment.

Base Realignment and Closure (BRAC)
Program governing the scheduled closing of Department of Defense sites. (Base Closure and Realignment Act of 1988, Public Law 100-526, 102 Stat. 2623, and the Defense Base Closure and Realignment Act of 1990, Public Law 101-510, 104 Stat. 1808)

Center of Expertise (CX)
A CX is a United States Army Corps of Engineers (USACE) organization that has been approved by Headquarters, USACE as having a unique or exceptional technical capability in a specialized subject area that is critical to other USACE commands. These services may be reimbursable or centrally funded.

Chemical Agent (CA)
A chemical compound intended for use (to include experimental compounds) that, through its chemical properties, produces lethal or other damaging effects on human beings, and is intended for use in military operations to kill, seriously injure, or incapacitate persons through its physiological effects. Excluded are research, development, test, and evaluation solutions, riot control agents, chemical defoliants and herbicides, smoke and other obscuration materials, flame and incendiary materials, and industrial chemicals. (DASA-ESOH Interim Guidance for Chemical Warfare Materiel (CWM) Responses, April 1, 2009)

Chemical Warfare Materiel (CWM)
Items generally configured as a munition containing a chemical compound that is intended to kill, seriously injure, or incapacitate a person through its physiological effects. CWM includes V- and G-series nerve agents or H-series (mustard) and L-series (lewisite) blister agents in other than-munition configurations; and certain industrial chemicals (e.g., hydrogen cyanide [AC], cyanogen chloride [CK], or carbonyl dichloride [called phosgene or CG]) configured as a military munition. Due to their hazards, prevalence, and military-unique application, only chemical agent identification sets (CAIS) that contain neat agent or dilute nerve agent are considered CWM. K951/952 are managed as CWM but for storage treatment and disposal are handled as hazardous waste in accordance with SAIE-ESOH 23 Apr 2007 memo: Treatment of chemical agent identification set (CAIS) as Hazardous Waste. CWM does not include: riot control devices; chemical defoliants and herbicides; industrial chemicals (e.g., AC, CK, CG) not configured as a munition; smoke and other obscuration producing items; flame and incendiary producing items; or soil, water, debris or other media contaminated with low concentrations of chemical agents where no chemical agent hazards exist._Soil, water, debris, or other media contaminated with dispersed V- and G- series nerve agent, H- and HN-series blister agent, or L will be considered and managed in accordance with 40 CFR 266 Subpart M. (DASA(ESOH) Interim Guidance for Chemical Warfare Materiel (CWM) Responses, April 1, 2009)

Chemical Weapon (CW)
Any munition or device containing or suspected of containing any chemical listed on the schedules in DASA-ESOH Interim Guidance for Chemical Warfare Materiel (CWM) Responses, April 1, 2009.

Community Relations Plan (CRP)
Formerly called the Public Involvement Plan, the CRP serves as the framework to establish a successful information exchange with the public during the Environmental Restoration Process. The CRP follows guidelines set forth under Comprehensive Environmental Response, Compensation, and Liability Act of 1980 and the Superfund Amendments and Reauthorization Act. Each CRP must be tailored to fit the individual site and situation and should also accommodate any site-specific agreements between the U.S. Army and the U.S. Environmental Protection Agency or state environmental agencies. The CRP is not a static document and should be revised to reflect the development and progress of actions at the site.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
Congress enacted CERCLA, commonly known as Superfund, on 11 December 1980. This law created a tax on the chemical and petroleum industries and provided broad Federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment.

Concentrated Munitions Use Area (CMUA)
CMUAs are munitions response sites (MRSs) or areas within MRSs where there is a high likelihood of finding unexploded ordnance or discarded military munitions and that have a high amount of munition debris within them as a result of historical munitions use and fragmentation. CMUAs are most commonly target areas on ranges; however, they also include explosion sites,

open burn / open detonation areas, and potentially even disposal sites where munitions have been disposed of over a relatively large area (i.e., not small, isolated burial pits).

<u>Conceptual Site Model (CSM)</u>
A CSM is a description of a site and its environment that is based on existing knowledge. It describes sources and receptors, and the interactions that link these. It assists the team in planning, data interpretation, and communication.

<u>Control Markers</u>
Project control markers may consist of markers and/or benchmarks established by any federal, state, local, or private agency with positional data within the minimum acceptable accuracy standards prescribed by the project team.

<u>Conventional Munitions and Explosives of Concern (MEC)</u>
The term "conventional MEC" refers to MEC (see definition) other than chemical warfare materiel, biological warfare materiel, and nuclear ordnance.

<u>Corrective Action</u>
The action taken to eliminate the causes of an existing nonconformity, defect, or other undesirable situation in order to prevent recurrence. (ER 5-1-11) Note: Following through with a corrective action is critical. In performing a corrective action, the Project Delivery Team should be careful not to simply correct the resultant symptoms of a systematic problem, but should seek to rectify the real cause behind the problem, as well as investigate if there are other aspects of the project that may have been affected by the systemic problem.

<u>Corrective Action Request (CAR)</u>
The CAR is a report documenting action to correct conditions adverse to quality.

<u>Customer</u>
The customer is a party, organization, or sponsor that depends upon the professional services, expertise, and advice of a project manager and technical personnel. Typically, the customer is the decision maker who is funding the project and responsible for the project property, such as the Department of Defense agencies, and sometimes the U.S. Environmental Protection Agency. The customer is a key member of the Project Delivery Team and should be encouraged to participate through the Technical Project Planning process.

<u>Data Quality Objective (DQO)</u>
A DQO is a qualitative and quantitative statement developed to clarify study objectives, define the type of data needed, and specify the tolerable levels of potential decision errors. A DQO is used as the basis for establishing the type, quality and quantity of data needed to support the decisions that will be made.

<u>Decision Document</u>
The Department of Defense has adopted the term Decision Document for the documentation of remedial action decisions at non-National Priorities List FUDS Properties. The decision document shall address the following: Purpose, Site Risk, Remedial Alternatives,

Public/Community Involvement, Declaration, and Approval and Signature. A Decision Document for sites not covered by an interagency agreement or Federal facility agreement is still required to follow a CERCLA response. All Decision Documents will be maintained in the Formerly Used Defense Sites Property/Project Administrative Record file. An Action Memorandum is the decision document for a removal response action.

Defense Environmental Restoration Program (DERP)
Congressionally authorized in 1986, DERP promotes and coordinates efforts for the evaluation and cleanup of contamination at Department of Defense installations and Formerly Used Defense Sites. (10 U.S.C. 2701 et. seq.)

Design Center (DC)
A specified U.S. Army Corps of Engineers (USACE) field office assigned a singular technical mission that is permanent and USACE-wide in scope. The designated office is to be considered the "lead activity" in a specialized area where capability needs to be concentrated for maximum effectiveness, economy, and efficiency. The Military Munitions Design Center (in coordination with the District Project Manager) will execute all phases of the Military Munitions Response Program response project after the approval of the Inventory Project Report unless the removal action is transferred to an approved District. (ER 1110-1-8153)

Discarded Military Munitions (DMM)
Military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal. The term does not include unexploded ordnance, military munitions that are being held for future use or planned disposal, or military munitions that have been properly disposed of consistent with applicable environmental laws and regulations. (10 U.S.C. 2710(e)(3))

Engineering Evaluation/Cost Analysis (EE/CA)
An EE/CA is prepared for all non-time-critical removal actions as required by Section 300.415(b)(4)(i) of the National Contingency Plan. The goals of the EE/CA are to identify the extent of a hazard, to identify the objectives of the removal action, and to analyze the various alternatives that may be used to satisfy these objectives for cost, effectiveness, and implementability.

Explosive Ordnance Disposal (EOD)
The detection, identification, onsite evaluation, rendering safe, recovery, and final disposal of unexploded ordnance and of other munitions that have become an imposing danger, for example by damage or deterioration.

Explosive Ordnance Disposal (EOD) Personnel
Military personnel who have graduated from the Naval School, Explosive Ordnance Disposal; are assigned to a military unit with a Service-defined EOD mission; and meet Service and assigned unit requirements to perform EOD duties. EOD personnel have received specialized training to address explosive and certain chemical agent hazards during both peacetime and wartime. EOD personnel are trained and equipped to perform render safe procedures on nuclear, biological, chemical, and conventional munitions, and on improvised explosive devices.

Explosive Soil
Because of some past munitions-related activities (e.g., settling ponds or explosives sumps at munitions production or demilitarization facilities), concentrations of explosives in soil (e.g., sand, sludge, clay) can exist such that the mixture itself presents an explosive hazard. DoD 6055.09-M, V7.E4.4 provides definitions and guidance for explosive soil.

Feasibility Study (FS)
A study undertaken to develop and evaluate alternatives for remedial action.

Formerly Used Defense Site (FUDS)
A FUDS is defined as a facility or site (property) that was under the jurisdiction of the Secretary of Defense and owned by, leased to, or otherwise possessed by the United States at the time of actions leading to contamination by hazardous substances. By the Defense Environmental Restoration Program policy, the FUDS program is limited to those real properties that were transferred from Department of Defense control prior to 17 October 1986. FUDS properties can be located within the 50 States, District of Columbia, Territories, Commonwealths, and possessions of the United States.

Formerly Used Defense Sites (FUDS) Project
A FUDS Project is a unique name given to an area of an eligible FUDS property containing one or more releases or threatened releases of a similar response nature, treated as a discrete entity or consolidated grouping for response purposes. This may include buildings, structures, impoundments, landfills, storage containers, or other areas where hazardous substance are or have come to be located, including FUDS eligible unsafe buildings or debris. Projects are categorized by actions described under installation restoration (hazardous, toxic, and radioactive waste [HTRW] and CON/HTRW), military munitions response program, or building demolition/debris removal. An eligible FUDS Property may have more than one project.

Geophysical Techniques
Techniques utilized for the detection and measurement of buried anomalies (e.g., ferromagnetic indicators and ground penetrating radar) to investigate the presence of munitions.

Hazardous Fragmentation Distance (HFD)
Distance at which the areal number density of hazardous fragments or debris becomes one per 600 square feet (55.7 square meters).

Hazardous, Toxic, and Radioactive Waste (HTRW) Activities
HTRW activities include those activities undertaken for the U.S. Environmental Protection Agency's Superfund program, the Defense Environmental Restoration Program, including the FUDS, and Installation Restoration Program sites at active Department of Defense facilities; HTRW actions associated with civil works projects; and any other mission or non-mission work performed for others at HTRW sites.

Intrusive Activity
An activity that involves or results in the penetration of the ground surface at an area known or suspected to contain munitions and explosives of concern. Intrusive activities can be of an investigative or removal action nature.

Land Use Controls (LUCs)
Physical, legal, or administrative mechanisms that restrict the use of, or limit access to, contaminated property to reduce risk to human health and the environment. Physical mechanisms encompass a variety of engineered remedies to contain or reduce contamination and physical barriers to limit access to property, such as fences or signs. The legal mechanisms are generally the same as those used for institutional controls (ICs) as discussed in the National Contingency Plan. ICs are a subset of LUCs and are primarily legal mechanisms imposed to ensure the continued effectiveness of land use restrictions imposed as part of a remedial decision. Legal mechanisms include restrictive covenants, negative easements, equitable servitudes, and deed notices. Administrative mechanisms include notices, adopted local land use plans and ordinances, construction permitting, or other existing land use management systems that may be used to ensure compliance with use restrictions. (DoD Management Guidance for the DERP)

Lead Regulatory Agency
States or tribes are generally the lead regulator for environmental investigations and response at non-National Priorities List (NPL) Formerly Used Defense Sites (FUDS). In certain circumstances, the U.S. Environmental Protection Agency (USEPA) may serve as lead regulator when the state or tribe requests USEPA assume the lead or when USEPA chooses to exert its lead regulator role. In cases where a non-NPL FUDS is on or affecting tribal land, the lead regulator role generally falls to the affected tribe. Project-specific circumstances may warrant assumption of the lead regulator role by USEPA. When a FUDS is either proposed for inclusion or listed on the NPL, USEPA is the lead regulator.

Mag & Flag
The use of geophysical equipment to survey an area in a real-time mode and mark the location of geophysical anomalies. This method is performed without using post data processing.

Material Potentially Presenting an Explosive Hazard (MPPEH)
Material owned or controlled by the Department of Defense that, prior to determination of its explosives safety status, potentially contains explosives or munitions (e.g., munitions containers and packaging material; munitions debris remaining after munitions use, demilitarization, or disposal; and range-related debris) or potentially contains a high enough concentration of explosives that the material presents an explosive hazard (e.g., equipment, drainage systems, holding tanks, piping, or ventilation ducts that were associated with munitions.

Maximum Fragmentation Distance (MFD)
The calculated maximum distance to which any fragment from the cylindrical portion of an ammunition and explosives (AE) case is expected to be thrown by the design mode detonation of a single AE item. This distance does not address fragments produced by sections of nose plugs, base plates, boat tails, or lugs. These special fragments, from the non-cylindrical portions of the AE case, can travel to significantly greater distances (i.e., more than 10,000 feet [3,048 meters])

than the calculated maximum distances. The maximum fragment distance also may be the measured distance, based on testing, to which any fragment from an AE item is thrown.

Military Munitions
Military munitions means all ammunition products and components produced or used by or for the U.S. Department of Defense (DoD) or the U.S. Armed Services for national defense and security, including military munitions under the control of the Department of Defense, the U.S. Coast Guard, the U.S. Department of Energy (DOE), and National Guard personnel. The term military munitions includes: confined gaseous, liquid, and solid propellants, explosives, pyrotechnics, chemical and riot control agents, smokes, and incendiaries used by DoD components, including bulk explosives and chemical warfare agents, chemical munitions, rockets, guided and ballistic missiles, bombs, warheads, mortar rounds, artillery ammunition, small arms ammunition, grenades, mines, torpedoes, depth charges, cluster munitions and dispensers, demolition charges, and devices and components thereof. Military munitions do not include wholly inert items, improvised explosive devices, and nuclear weapons, nuclear devices, and nuclear components thereof. However, the term does include non-nuclear components of nuclear devices, managed under DOE's nuclear weapons program after all required sanitization operations under the Atomic Energy Act of 1954, as amended, have been completed. (40 CFR 260.10)

Military Munitions Response Program (MMRP)
The MMRP category is defined as response actions (i.e., the identification, investigation, and remedial actions, or a combination of removal and remedial actions) to address munitions and explosives of concern or munitions constituents. This includes the removal of foreign military munitions if it is incidental to the response addressing Department of Defense military munitions at a Formerly Used Defense Sites property. (ER 200-3-1)

Military Range
Designated land or water area set aside, managed, and used to conduct research on, develop, test, and evaluate military munitions and explosives, other ordnance, or weapon systems, or to train military personnel in their use and handling. Ranges include firing lines and positions, maneuver areas, firing lanes, test pads, detonation pads, impact areas, and buffer zones with restricted access and exclusionary areas. (Military Munitions Rule, 40 CFR. 266.201)

Munitions and Explosives of Concern (MEC)
This term, which distinguishes specific categories of military munitions that may pose unique explosives safety risks, means:
(a) unexploded ordnance, as defined in 10 U.S.C. 2710 (e) (9);
(b) discarded military munitions, as defined in 10 U.S.C. 2710 (e) (2), or
(c) munitions constituents (e.g., TNT, RDX) present in high enough concentrations to pose an explosive hazard.

Munitions Constituents (MC)
Any materials originating from unexploded ordnance, discarded military munitions, or other military munitions, including explosive and non-explosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions. (10 U.S.C. 2710(e)(3))

<u>Munitions Response (MR)</u>
Response actions, including investigation, removal and remedial actions to address the explosives safety, human health, or environmental risks presented by unexploded ordnance, discarded military munitions, or munitions constituents.

<u>Munitions Response Area (MRA)</u>
Any area on a defense site that is known or suspected to contain unexploded ordnance, discarded military munitions, or munitions constituents. Examples include former ranges and munitions burial areas. An MRA is comprised of one or more munitions response sites.

<u>Munitions Response Explosives Siting Plan (MRESP)</u>
The munitions response explosives safety submission required for munitions response investigation or characterization that involves intentional physical contact with munitions and explosives of concern (MEC). The MRESP address areas (e.g., magazines) used for the storage of commercial or military demolition explosives, recovered MEC, planned or established demolition or disposal areas; and the munitions response area, munitions response site, or response area boundaries.

<u>Munitions Response Explosives Safety Submission (MRESS)</u>
The document which serves as the specifications for conducting work activities at the project. The MRESS details the scope of the project, the planned work activities, and potential hazards (including the maximum credible event) and the methods for their control.

<u>Munitions Response Site (MRS)</u>
A discrete location within a munitions response area that is known to require a munitions response.

<u>National Oil and Hazardous Substance Pollution Contingency Plan (NCP)</u>
Revised in 1990, the NCP provides the regulatory framework for responses under CERCLA. The NCP designates the Department of Defense as the removal response authority for ordnance and explosives hazards.

<u>Non-Concentrated Munitions Use Area (NCMUA)</u>
NCMUAs are munitions response sites (MRSs) or areas within an MRS where there is a low amount of munitions debris or unexploded ordnance due to limited historical munitions use and fragmentation. NCMUAs may be either entire MRSs (e.g., training and maneuver areas) or they may be a portion of an MRS outside of a concentrated munitions use area (e.g., buffer areas).

<u>Non-Stockpile Chemical Warfare Materiel (NSCWM)</u>
Chemical warfare materiel (CWM; see definition) that is not included in the chemical stockpile. NSCWM is divided into five categories: buried CWM, recovered chemical weapons (items recovered during range clearing operations, from chemical burial sites, and from research and development testing), former chemical weapon production facilities, binary chemical weapons, and miscellaneous CWM (unfilled munitions and devices and equipment specially designed for use directly in connection with employment of chemical weapons).

Ordnance and Explosives Safety Specialist (OESS)
U.S. Army Corps of Engineers personnel, classified as a GS-0018 Safety Specialist, and who is unexploded ordnance-qualified. OESS perform safety, quality assurance and Military Munitions Design Center (MMDC) functions for the government. The OESS may reside in and report to the construction field office or may reside in the engineering/construction office within the MMDC.

Preliminary Assessment (PA)
The PA is a limited-scope investigation that collects readily available information about a project and its surrounding area after the property has been determined to be Military Munitions Response Program eligible. The PA is conducted on a property-wide basis and evaluates all potential projects and hazards. Regardless of the number of categories of hazards present hazardous, toxic, and radioactive waste (HTRW), unexploded ordnance / discarded military munitions / munitions constituents, building demolition/debris removal, etc.), only one PA will be prepared for the property. For Formerly Used Defense Sites, the PA will comply with the requirements in ER 200-3-1. The PA is designed to distinguish, based on limited data, between sites that pose little or no threat to human health and the environment and sites that may pose a threat and require further investigation. The PA also identifies sites requiring assessment for possible removal actions and helps set priorities for Site Inspections by collecting enough information to fill out at least one of the Munitions Response Site Prioritization Protocol modules. If the PA results in a recommendation for further investigation, a Site Inspection is performed.

Project Delivery Team (PDT)
The PDT is a multi-disciplined project team lead by the Project Manager with responsibility for assuring that the project stays focused, first and foremost on the public interest, and on the customer's needs and expectations, and that all work is integrated and done in accordance with a Project Management Plan and approved business and quality management processes. The PDT focuses on quality project delivery, with heavy reliance on partnering and relationship development to achieve better performance. The PDT shall consist of everyone necessary for successful development and execution of all phases of the project. The PDT will include the customers, the Project Manager, technical experts within or outside the local U.S. Army Corps of Engineers activity, specialists, consultants/contractors, stakeholders, representatives from other Federal and state agencies, and higher level members from Division and Headquarters who are necessary to effectively develop and deliver the project actions. The customer is an integral part of the PDT. (ER 5-1-11)

Project Management Plan (PMP)
A living document used to define expected outcomes and guide execution and control of project (or program) actions. Primary uses of the PMP are to facilitate communication among participants, assign responsibilities, define assumptions, and document decisions. Establishes baseline plans for scope, cost, schedule, safety, and quality objectives against which performance can be measured, and to adjust these plans as actual performance dictates. The project delivery team develops the PMP.

Project Manager (PM)
The PM is responsible for management and leadership of a project during its entire life cycle, even when more than one U.S. Army Corps of Engineers District or activity is involved. The PM will generally reside at the geographic District but can be elsewhere as needed. The PM and Project Delivery Team (PDT) are responsible and accountable for ensuring the team takes effective, coordinated actions to deliver the completed project according to the Project Management Plan. The PM manages all project resources, information and commitments, and leads and facilitates the PDT towards effective development and execution of project actions. (ER 5-1-11)

Quality
The totality of features and characteristics of a product or service that bear on its ability to meet the stated or implied needs and expectations of the project. Quality expectations need to be negotiated among the Project Delivery Team members (which includes the customer) and are set in the Project Management Plan. (ER 5-1-11). More specifically, the quality of a response action is measured by how closely that response action meets the standards and expectations of the customer.

Quality Assurance (QA)
An integrated system of management activities involving planning, implementation, assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed to meet project requirements defined in the Project Management Plan.

Quality Assurance Project Plan (QAPP)
A formal document describing in comprehensive detail the necessary quality assurance, quality control, and other technical activities that must be implemented to ensure that the results of the work performed will satisfy the stated performance criteria of the project.

Quality Assurance Surveillance Plan (QASP)
All service contracts require the development and implementation of a QASP. A QASP describes how government personnel will evaluate and assess contractor performance. The purpose of the QASP is to describe how project performance will be measured and assessed against performance standards. It is based on the premise that the contractor, not the government, is responsible for managing quality control.

Quality Control (QC)
The overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established in the Project Management Plan; operational techniques and activities that are used to fulfill requirements for quality.

Quality Management
Processes required to ensure that the actions at the project would satisfy the needs and objectives for which it was undertaken, consisting of quality planning, quality assurance, quality control, and quality improvement.

Quality System
A structured and documented management system describing the policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan of an organization for ensuring quality in its work processes, products (items), and services. The quality system provides the framework for planning, implementation, and assessing work performed by the organization and for carrying out required quality assurance and quality control. (ER 5-1-11).

Quantity-Distance (Q-D)
The quantity of explosives material and distance separation relationships that provide defined types of protection. These relationships are based on levels of risk considered acceptable for the stipulated exposures and are tabulated in the appropriate Q-D tables provided in Department of Defense Manual 6055.09. Separation distances are not absolute safe distances but are relative protective safe distances. Greater distances than those shown in the Q-D tables will be used whenever possible. (DoDM 6055.09)

Remedial or Remedial Action (RA)
Those actions consistent with permanent remedy taken instead of or in addition to removal actions in the event of a release or threatened release of a hazardous substance into the environment, to prevent or minimize the release of hazardous substances so that they do not migrate to cause substantial danger to present or future public health, welfare or the environment. The term includes, but is not limited to, such actions at the location of the release as storage; confinement; perimeter protection using dikes, trenches, or ditches; clay cover; neutralization; cleanup of released hazardous substances and associated contaminated materials; recycling or reuse; diversion; destruction; segregation of reactive wastes; dredging or excavations; repair or replacement of leaking containers; collection of leachate and runoff; onsite treatment or incineration; provision of alternative water supplies; and any monitoring reasonably required to assure that such actions protect the public health, welfare and the environment. The term includes the costs of permanent relocation of residents and businesses and community facilities where the President determines that, alone or in combination with other measures, such relocation is more cost-effective and environmentally preferable to the transportation, storage, treatment, destruction, or secure disposition offsite of hazardous substances, or may otherwise be necessary to protect the public health or welfare. The term includes offsite transport and offsite storage, treatment, destruction, or secure disposition of hazardous substances and associated contaminated materials. (DoD Management Guidance for the DERP)

Remedial Design (RD)
A phase of remedial action that follows the remedial investigation/feasibility study and includes development of engineering drawings and specifications for a site cleanup.

Remedial Investigation (RI)
Process undertaken to determine the nature and extent of the problem presented by a release which emphasizes data collection and site characterization. The RI is generally performed concurrently and in an interdependent fashion with the feasibility study.

Remedial Investigation / Feasibility Study (RI/FS)
See separate definitions for RI and FS.

Removal or Removal Action

The cleanup or removal of released hazardous substances from the environment. Such actions may be taken in the event of the threat of release of hazardous substances into the environment, such actions as may be necessary to monitor, assess, and evaluate the release or threat of release of hazardous substances, the disposal of removed material, or the taking of such other actions as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or to the environment, which may otherwise result from a release or threat of release. The term includes, in addition, without being limited to, security fencing or other measures to limit access, provision of alternative water supplies, temporary evacuation and housing of threatened individuals not otherwise provided for, action taken under section 9604(b) of this title, and any emergency assistance which may be provided under the Disaster Relief and Emergency Assistance Act [42 U.S.C. 5121 et seq.] The requirements for removal actions are addressed in 40 CFR §§300.410 and 330.415. The three types of removals are emergency, time-critical, and non time-critical removals. (DoD Management Guidance for the DERP)

Resource Conservation and Recovery Act (RCRA)
Enacted in 1976, RCRA promotes the protection of health and the environment. It regulates waste generation, treatment, storage, transportation, and disposal for facilities currently in operation.

Response Action
A CERCLA-authorized action involving either a short-term removal action or a long-term removal response. This may include, but is not limited to, removing hazardous materials, containing or treating the waste on-site, and identifying and removing the sources of ground water contamination and halting further migration of contaminants.

Restoration Advisory Board (RAB)
A Restoration Advisory Board (RAB) is a forum for the discussion and exchange of information between representatives of the Department of Defense, regulators, state and local governments, tribal governments, and the affected community. RABs provide an opportunity for stakeholders to have a voice and actively participate in the review of technical documents, to review restoration progress, and to provide individual advice to decision makers regarding restoration activities at Formerly Used Defense Sites Properties and Projects.

Site Inspection (SI)
Activities undertaken to determine whether there is a release or potential release and the nature associated threats. The purpose is to augment the data collected in the Preliminary Assessment and to generate, if necessary, sampling and other field data to determine the presence, type, distribution, density and location of ordnance and explosives.

Stakeholder
Stakeholders include federal, state, and local officials, tribal officials, community organizations, property owners, and others having a personal interest or involvement or having a monetary or commercial involvement in the Formerly Used Defense Sites Property that is to undergo a remedial/response action.

Technical Project Planning (TPP)
The process for designing data collection programs at Formerly Used Defense Sites properties. The TPP process helps ensure that the requisite type, quality, and quantity of data are obtained to satisfy project objectives that lead to informed decisions and project/property closeout.

Time-Critical Removal Action (TCRA)
A TCRA is a response to a release or threat of release that poses such a risk to public health (serious injury or death), or the environment, that clean up or stabilization actions must be initiated within six months.

Tribes
Federally recognized American Indian and Alaskan Native governments.

Uniform Federal Policy – Quality Assurance Project Plan (UFP-QAPP)
Consensus document prepared by the Intergovernmental Data Quality Task Force that provides instructions for preparing Quality Assurance Project Plans for any environmental data collection operation.

Unexploded Ordnance (UXO)
Military munitions that (a) have been primed, fuzed, armed, or otherwise prepared for action; (b) have been fired, dropped, launched, projected or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material; and (c) remain unexploded either by malfunction, design, or any other cause. (U.S.C. 2710 (e) (9))

Unexploded Ordnance (UXO)-Qualified Personnel
Personnel who have performed successfully in military explosive ordnance disposal positions, or are qualified to perform in the following Department of Labor, Service Contract Act, Directory of Occupations, contractor positions: UXO Technician II, UXO Technician III, UXO Safety Officer, UXO Quality Control Specialist, or Senior UXO Supervisor.

Unexploded Ordnance (UXO) Technicians
Personnel who are qualified for and filling Department of Labor, Service Contract Act, Directory of Occupations, contractor positions of UXO Technician I, UXO Technician II, and UXO Technician III.