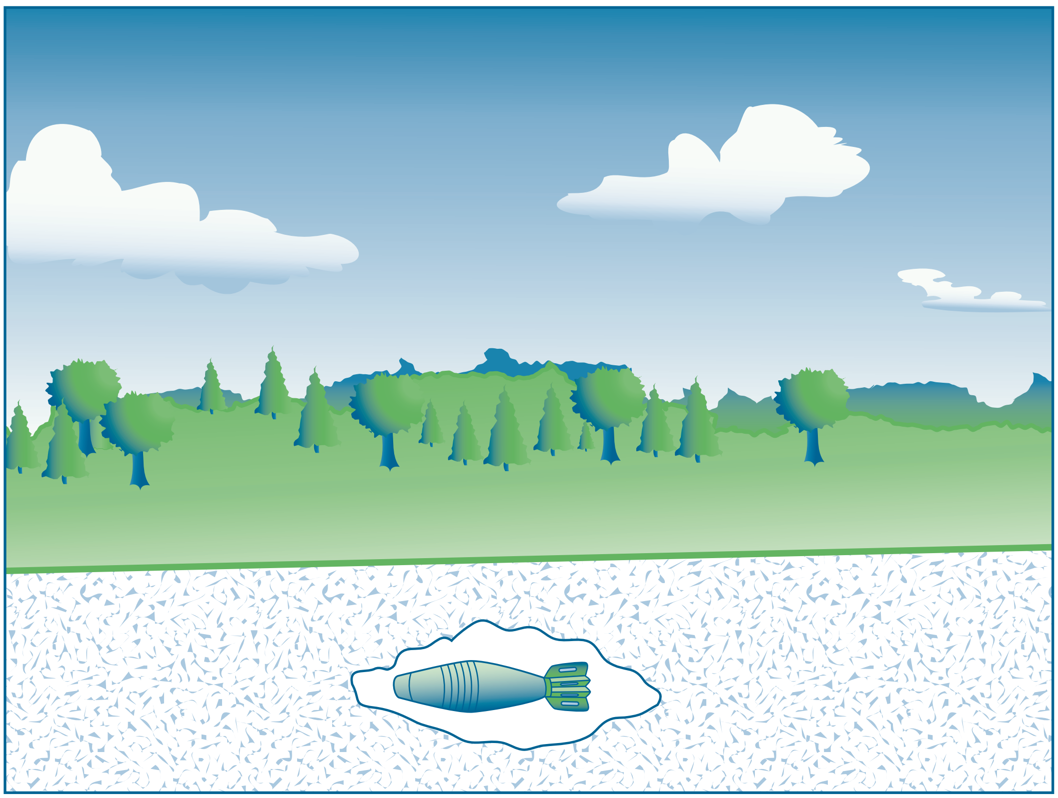
INTERSTATE TECHNOLOGY & REGULATORY COUNCIL

Technical/Regulatory Guideline

Quality Considerations for Munitions Response Projects



October 2008

Prepared by
The Interstate Technology & Regulatory Council
Unexploded Ordnance Team

ABOUT ITRC

Established in 1995, the Interstate Technology & Regulatory Council (ITRC) is a state-led, national coalition of personnel from the environmental regulatory agencies of all 50 states and the District of Columbia, three federal agencies, tribes, and public and industry stakeholders. The organization is devoted to reducing barriers to, and speeding interstate deployment of, better, more cost-effective, innovative environmental techniques. ITRC operates as a committee of the Environmental Research Institute of the States (ERIS), a Section 501(c)(3) public charity that supports the Environmental Council of the States (ECOS) through its educational and research activities aimed at improving the environment in the United States and providing a forum for state environmental policy makers. More information about ITRC and its available products and services can be found on the Internet at www.itrcweb.org.

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UXO-5

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ITRC (Interstate Technology & Regulatory Council). 2008. *Quality Considerations for Munitions Response Projects*. UXO-5. Washington, D.C.: Interstate Technology & Regulatory Council, Unexploded Ordnance Team. www.itrcweb.org.

ACKNOWLEDGEMENTS

The members of the Interstate Technology & Regulatory Council (ITRC) Unexploded Ordnance (UXO) Team wish to acknowledge the individuals, organizations, and agencies that contributed to this document.

As part of the broader ITRC effort, the UXO Team effort is funded primarily by the U.S. Department of Energy. Additional funding and support have been provided by the U.S. Department of Defense (DOD) and the U.S. Environmental Protection Agency (EPA). ITRC operates as a committee of the Environmental Research Institute of the States (ERIS), a Section 501(c)(3) public charity that supports the Environmental Council of the States (ECOS) through its educational and research activities aimed at improving the environment in the United States and providing a forum for state environmental policy makers.

Members of the ITRC UXO Team (listed in Appendix B) participated in the writing and reviewing of the document. The UXO Team also thanks the organizations that made the expertise of these individuals available to the ITRC. Primary authors of the document include the following individuals:

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The UXO Team thanks Clif Youmans of the Montana Army National Guard and Linda Daehn of Tetra Tech EM Inc. for contributing *Quality Assurance and Quality Control in UXO Remediation—A Case Study from Montana* for inclusion in this document.

The UXO Team thanks Daniel Ruedy and Aimee Houghton, current and past ITRC UXO Team Program Advisors, for providing the many hours of administrative and technical support and advice that were required to produce this document.

The UXO Team would also like to acknowledge the following individuals and organizations that provided valuable comments, input, and suggestions for this document's improvement.

- U.S. Army
- U.S. Army Corps of Engineers
- U.S. Army Environmental Command
- Ann Charles, New Jersey Department of Environmental Protection
- David Larsen, Utah Division of Solid and Hazardous Waste
- Nebraska Department of Environmental Quality
- Mohammed Ghazi, Georgia Environmental Protection Division
- Bonnie Buthker, Ohio Environmental Protection Agency
- Kevin Oates, U.S. Environmental Protection Agency
- John McCabe, Michigan Department of Environmental Quality
- Strategic Environmental Research and Development Program (SERDP)/Environmental Security Technology Certification Program (ESTCP)
- U.S. Navy

EXECUTIVE SUMMARY

In this document the ITRC Unexploded Ordnance (UXO) Team provides guidance to environmental regulators on how to define quality, how to systematically plan for and achieve quality results, and how to apply these concepts to processes common to a munitions response (MR) project. The document also provides real-world examples to illustrate how the proper or improper application of the quality concepts presented in this document affect the "quality" of MR projects.

In this document, quality is defined as "conformance to requirements." To manage quality, the quality requirements of the project must first be understood. Requirements must be precisely stated and clearly understood by everyone involved. A plan is then put in place to meet those requirements.

The UXO Team emphasizes taking a whole-system approach to designing and managing an MR project to optimize quality. Whole-system design means optimizing not just parts, but the <u>entire system</u> (in this case the MR). Practically speaking, the UXO Team views MR as a system made of processes, subprocesses, and tasks. Therefore, a process approach to planning and managing MR projects is recommended.

An MR plan properly developed using the process approach will contain quality control (QC) and quality assurance (QA) activities that need to be performed. QC activities are focused on the deliverable itself. QA activities are focused on the process used to create the deliverable. QA and QC are both powerful techniques, and both must be performed to ensure that the deliverables meet the customer's quality requirements.

Through the proper application of a process approach to plan and manage an MR project, the MR project should produce results of verifiable quality with sufficient QA and QC documentation for defensible decision making.

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QUALITY CONSIDERATIONS FOR MUNITIONS RESPONSE PROJECTS

1. INTRODUCTION

The purpose of this document is to provide guidance to environmental regulators on how to define quality, systematically plan for and achieve quality results, and apply these concepts to processes common to a munitions response (MR) project. MR projects are actions taken to address the explosive safety hazards, human health, or environmental risks presented by munitions and explosives of concern (MEC, see box) and munitions constituents. This document addresses the detection and removal, treatment, and disposal of only unexploded ordnance (UXO) and discarded military munitions (DMM).

> **A Note on MEC**
>
> Munitions and explosives of concern (MEC) includes unexploded ordnance (UXO), discarded military munitions (DMM), and munitions constituents present in high enough concentrations to pose an explosive hazard. However, this document addresses only UXO and DMM.

This document is a companion to previous Interstate Technology & Regulatory Council (ITRC) UXO Team documents and trainings, including the UXO Basic Training two-day class, the Site Investigation/Site Remediation Internet-Based Training, *Breaking Barriers to the Use of Innovative Technologies: State Regulatory Role in Unexploded Ordnance Detection and Characterization Technology Selection* (ITRC 2000), *Munitions Response Historical Records Review* (ITRC 2003), *Geophysical Prove-Outs for Munitions Response Projects* (ITRC 2004), and *Survey of Munitions Response Technologies* (ITRC 2006, in collaboration with the Strategic Environmental Research and Development Program [SERDP] and the Environmental Security Technology Certification Program [ESTCP]). See box at right for descriptions of these documents.

> **Previous ITRC UXO Team Documents**
>
> This document assumes a basic understanding of UXO and MR projects. The reader is encouraged to review the following companion documents:
>
> *Breaking Barriers to the Use of Innovative Technologies: State Regulatory Role in Unexploded Ordnance Detection and Characterization Technology Selection* (ITRC 2000) provides an analysis of case studies that supports early and meaningful state regulatory involvement in the selection of innovative UXO characterization technologies.
>
> *Munitions Response Historical Records Review* (ITRC 2003) is a guide for regulators, stakeholders, and others involved in oversight of historical records review projects on MR sites.
>
> *Geophysical Prove-Outs for Munitions Response Projects* (ITRC 2004) provides information on geophysical prove-outs and the broader topics of geophysical surveys, equipment, and methodologies currently used in MR actions.
>
> *Survey of Munitions Response Technologies* ITRC 2006, with SERDP and ESTCP) is a valuable resource for project managers and personnel working on MR sites. It provides an overview of the current status of technologies used for MR actions and, where possible, evaluates and quantifies their performance capabilities.

The goal of this document is to emphasize taking a whole-system approach to designing and managing an MR project to optimize "quality." Whole-system design means optimizing not just parts, but the <u>entire system</u> (in this case the MR). Practically speaking, the UXO Team views the MR as a system made of processes, subprocesses, and tasks. Therefore, the UXO Team supports a process approach to planning and managing MR projects. Naturally, this is more difficult at first. It takes ingenuity, intuition, experience, and teamwork. Everything must be considered simultaneously and teased apart to reveal key processes, process interactions, process requirements, and controls.

A process approach is a powerful way to plan, organize, and manage how work activities produce value (quality) for the "customer" (see box). A process is an activity that transforms inputs into outputs. A process is made of people, tasks, records, documents, forms, resources, rules, regulations, reports, materials, supplies, tools, equipment, and so on—all the things that are necessary to transform inputs into outputs.

Customers

A **customer** is someone who is impacted by the product. Current quality practices recognize customers as being both external to an organization or function and internal, within an organization.

A process approach is a systematic planning strategy. When a project team uses a process approach, it means that it manages the processes required to produce the desired product or service, the interaction between these processes, and the inputs and outputs that bind these processes together into a system.

A process approach ensures that all participants understand the needs and expectations of the customer. It also results in a project's logical development, efficient use of resources, transparency of intent and direction, defensibility of project results, and appropriate documentation. The process approach is central to the way quality management is addressed in this document.

1.1 Scope of this Document

The quality concepts presented in this document are intended to be applicable to all U.S. Department of Defense (DOD) component programs (U.S. Army, U.S. Navy, etc.) and federal and state regulatory agencies. Though this document discusses certain aspects of quality systems and quality management plans, it also assumes a level of familiarity with basic quality concepts. For more detailed discussions of the role of quality in project management, the reader is encouraged to take advantage of existing resources such as the American Society for Quality Web site (www.asq.org).

References Used in this Document

The UXO Team recognizes that Web-based documents and Web pages are subject to movement and closure. When possible, the UXO Team has elected to house copies of such Web-based resources cited in this document on its team page. The reader is encouraged to access these and other resources at www.itrcweb.org/teampublic_UXO.asp.

This document follows requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP), including the CERCLA response process. However, this document focuses primarily on the processes of an MR project for UXO/DMM.

This document is also consistent with guidance provided in *Uniform Federal Policy for Quality Assurance Project Plans* (UFP-QAPP, EPA/DOD/DOE 2005a, b, c). The UFP-QAPP is the product of an extensive collaborative effort by management- and working-level U.S. Environmental Protection Agency (EPA), DOD, and U.S. Department of Energy (DOE) personnel. It was created to address the real and perceived inconsistencies and deficiencies in data quality that result in greater costs, time delays, and the potential for response actions that result in unaddressed risk. The UFP-QAPP employs a process approach designed to encourage a level of detail consistent with the scope and complexity of the project. It is a tool that can be used for many different projects, and its use can promote cost-effectiveness. EPA has issued a directive and guidance requiring EPA Regions to use the UFP-QAPP at federal facilities involving CERCLA, Resource Conservation and Recovery Act (RCRA), and brownfield-type projects. DOD has also requested that all DOD components implement the UFP-QAPP for all DOD environmental projects, including MR. Therefore, state regulators are encouraged to become familiar with the requirements of these documents and understand how they can impact their MR projects. The UFP-QAPP and associated support tools are available at www.epa.gov. More information on the UFP-QAPP and its applications to MR is provided as a case study in section 4.5.

1.2 Document Organization

Following this introduction, section 2 discusses some general quality concepts for MR projects. Section 3 discusses implementation, analysis, corrective action, and improvement specific to the quality process for MR projects. Section 4 includes case studies and lessons learned. Section 5 provides a summary and conclusion. Section 6 is the reference list. Appendix A explains the review process and where to find comments and team responses. Appendix B lists UXO Team member contact information, Appendix C is a glossary of terms, and Appendix D defines acronyms used in the text.

1.3 Quality Concepts

A quality system is a structured and documented management system describing policies, objectives, principles, organizational authority, responsibilities, accountability, and an implementation plan of an organization for ensuring quality in its work process and products (EPA/DOD/DOE 2005a).

A Quality Management Plan (QMP) is a formal document describing an organization’s quality system in terms of the organizational structure; policy and procedures; functional responsibilities of management and staff; lines of authority; and needed interfaces for those planning, implementing, documenting, and assessing all activities conducted (EPA/DOD/DOE 2005a).

Quality assurance (QA) is an integrated system of policies and procedures for planning, implementation, documentation, assessment, reporting, and quality improvement to ensure that a process, item, or activity is of the type and quality required for a process and products (EPA/DOD/DOE 2005a).

Quality control (QC) is the overall system of technical activities that measures the attributes and performance of a process, item, or activity against defined standards to verify that it meets the stated specifications. QC involves the action of testing, measuring, and evaluating the effectiveness of the program or activity. Examples include duplicate sampling, calibration checks, audits, reviews, assessments, peer reviews, and management oversight activities (EPA/DOD/DOE 2005a).

A Quality Assurance Project Plan (QAPP) is a formal document that describes, in comprehensive detail, the necessary QA/QC and other technical activities that must be implemented to ensure that the results of the work performed will satisfy predetermined performance requirements (EPA/DOD/DOE 2005a).

1.4 Munitions Response Project Quality Management Plans

Along with the UFP-QAPP, DOD components have developed QMPs that describe their policies regarding quality. QMPs for the individual DOD components should be made available by the DOD representative responsible for the project. When assessing a quality plan for an MR project, the regulator should be familiar with the appropriate QMP to understand the specific requirements and guidelines of the DOD component responsible for the MR project.

1.5 The State Regulator's Responsibility in Quality Oversight

The regulator's responsibility on an MR project is to ensure that the project complies with pertinent state and federal rules and regulations and meets the requirements for characterization, cleanup, and/or site closure. Regulatory concurrence of an MR project depends heavily on the quality of site characterization and cleanup efforts. For this reason, the importance of "up-front" regulator involvement in determining project objectives and quality requirements and establishing the quantity and quality of data needed to support a decision should not be underestimated. Therefore, the regulator should be involved early on in decisions regarding project objectives; the identification of key processes; and the type, quantity, and quality of data required for process control and process documentation.

2. QUALITY

The purpose of this section is to introduce basic quality concepts and describe how these concepts can be applied to an MR project. More importantly, the information provided here is intended to help the reader develop a consistent method for managing quality by implementing a process approach to quality management. Quality is achieved more efficiently when key activities and related resources are managed as a process.

For the purposes of this document, "quality" is defined as "conformance to requirements." To manage quality, the quality needs of the customer must first be understood. Requirements must be precisely stated and clearly understood by everyone involved. Measurements and observations are then performed to determine conformance to those requirements. Any nonconformance detected indicates an absence of quality. Quality problems become nonconformance problems, and quality becomes definable.

A Note on Requirements

A **requirement** is a documented specification for a product or service. In theory, good requirements should be

- necessary
- unambiguous
- concise
- consistent
- complete
- attainable
- verifiable

Identifying key processes and quality requirements is vital to the success of an MR project. MR processes and requirements for those processes should be described, executed, and documented in such a manner that, upon completion, decision makers will know with a high degree of confidence that the right things were done at the right time and in the right way.

2.1 The Process Approach

A process approach is a powerful method of organizing and managing how work activities produce quality for the customer. A process is "an organized group of related activities that work together to transform one or more kinds of input into outputs that are of value to the customer" (Hammer 2001). This definition's implications are as follows:

- A process is a group of activities, not just one.
- The activities that make up a process are neither random nor ad hoc; they are related and organized.
- All the activities in a process must work together toward a common goal.
- Processes exist to produce results that customers—either internal (within an organization, such as a department) or external (outside an organization, such as paying customers)—care about.

In implementing a process approach to quality, managers strive to systematically ensure that all processes, subprocesses, and tasks are properly planned, executed, and documented. A successful approach requires that these be performed in such a manner that, upon completion of the tasks, overall results are effectively and efficiently attained and, more importantly, meet requirements. Generally, this goal is accomplished by the following:

- breaking down the overall project into processes, subprocesses, and tasks
- developing metrics and a measurement system for each of these, including goals and error limits, which, if adequately implemented, will ensure that the final "product" meets the requirements
- implementing control measures to ensure that requirements are consistently achieved or that deficiencies are identified and corrected
- continually assessing the entire system of controls to ensure that it is working (If it is not, appropriate modifications can be made.)

Some opportunities to implement improvements as the process progresses are as follows:

- Improve the flow (of material, teams, tasking, processing, data, etc.).
- Identify and eliminate unnecessary redundancies.
- Move quality inspections further "upstream" (away from the finished product) in the process to prevent wasteful processing of nonconformities. If possible, determine what new requirements need to be developed.

In summary, implementing a process approach to managing quality will help environmental regulators and stakeholders to achieve the following:

- Focus on the desired result (i.e., start with the end in mind).
- Systematically define the tasks and subtasks necessary to obtain the desired result.
- Establish clear responsibility and accountability for managing key activities.

- Identify the interfaces of key activities within and between the functions of the organization.
- Develop quality requirements.
- Establish monitoring activities to ensure conformance to requirements.
- Perform monitoring activities.
- Identify quality issues (nonconformance) and quality improvement actions.
- Report on the overall level of quality achieved (documentation).

2.2 Quality Assurance and Quality Control

The terms QA and QC are often used interchangeably to refer to ways of ensuring the quality of a service or product. However, the terms have different meanings.

QC is product oriented. It is the techniques or activities designed to evaluate a completed task or product. QC activities focus on finding defects in specific deliverables. In effect, QC is determined by the comparison of a product against the requirements that were developed for the product before the product existed. Examples of QC include walkthroughs and product testing or end-of-task inspections. Typical QC steps are problem identification, problem analysis, problem correction, and feedback to QA. QC tasks are usually carried out by those directly associated with the production of a product.

QA is process oriented. QA is the development of the processes that will determine the template and pattern of QC tasks. QA activities ensure that all processes are defined and appropriate. Therefore, a QA review focuses on the process elements of a project (e.g., whether requirements being defined at the proper level of detail). Examples of QA activities are process development, identifying methods, developing requirements, problem trend analysis, and process improvement. Examples of QA tools are process checklists and project audits. QA evaluators can be a manager, a client, or even a third-party auditor.

QA and QC are powerful techniques. Both must be performed to ensure that the deliverables meet the quality requirements of the customer. Planners using a process approach to plan the project will, by virtue of the planning process, identify QA and QC activities that need to be performed to ensure confidence in the quality of the product.

2.2.1 Quality Assurance Project Plan

Properly implemented, the process approach should generate a plan that identifies all necessary QA and QC activities that must be performed during the MR project. Once identified, the QA/QC activities and data requirements are assimilated into a document often referred to as the QAPP.

The QAPP should contain and describe in detail specific data or information required that must be collected to demonstrate conformance to requirements. It should specify what, how, when, and by whom the data will be collected. The QAPP should also detail how data will be assessed, analyzed, documented, and reported and include ways to ensure data precision, integrity, and traceability. The emphasis on data quality and integrity cannot be overemphasized. “Good” data provide confidence that the tasks or processes were implemented properly and the product produced meets quality requirements. Good data provide legally defensible decision making. To this end, the UXO Team recommends following EPA's data quality objective (DQO) guidance to assist in identifying data quality for MR QA/QC activities.

> **A Note on DQOs**
>
> A **DQO** is a systematic planning tool used to establish criteria for data quality, to define tolerable error rates, and to develop a data collection design to support decisions (EPA 1993).

The QAPP should cover the entire scope of the MR project. After the MR project is complete, the QAPP—along with all the completed QA/QC forms and records—should be able to stand on its own as the record of quality for the MR project. A suggested format for an MR QAPP is the EPA's UFP-QAPP manual, modified to incorporate MR-specific requirements, including all of the important explosive safety aspects (see section 4.5).

2.2.2 Variations in QC Monitoring Data

QC monitoring data from individual inspection points usually contain variances. An inspection point that consistently produces identical data is highly unlikely. Some variance in the data, often referred to as "common cause" variance, is the result of limitations in the instruments or activities performed. Common cause variations are unavoidable, always present in any measurement, and difficult, if not impossible, to reduce. For example, suppose the positioning checks for a geophysical detector randomly vary 4–15 cm from the reference point. Typically, 25 cm is an acceptable requirement for position accuracy. If the agreed-to positioning requirement was set by the project team at 25 cm, positioning checks—even with the variance—would meet the requirement for accuracy. If a higher level of accuracy is desired, a more accurate method of navigation would be required. If the monitoring requirements are too stringent, they might be beyond the capability of the instruments. In this case, the requirements would have to change, or a better positioning device would have to be used (or developed if not available).

Variations in monitoring data that are not common cause are assumed to be "special" cause. Special cause variations indicate that something has gone wrong or is going wrong in the process. When the variation exceeds the established QC monitoring requirement or is trending in that direction, the monitoring system should have a mechanism that initiates a root cause analysis. Once the root cause is identified, a corrective action can be determined, implemented, and documented. For example, assume the positioning accuracy for a navigation system has been varying 5–24 cm and has been steadily trending toward the 25 cm data requirement. Under these circumstances, a root cause analysis should be initiated to determine what is causing the degradation in navigation accuracy that is trending close to nonconformance. The root cause analysis may, for example, determine that the instrument was not properly calibrated because a substitute team member was unfamiliar with the calibration process. An appropriate corrective action in this case might be to require that all new team members and team members returning after an extended absence be trained or retrained on the calibration process.

2.2.3 Nonconformance (QA/QC Failures)

The fundamental rule of QA/QC is to meet requirements at all times. However, situations can arise in which requirements are not or cannot be met. In such cases, the person responsible for the process, instrument, or product exhibiting the nonconformance (QA/QC failure) must have the authority to stop the process and implement corrective actions.

All workers must understand that any departure from requirements must be recorded, reviewed, and resolved by the proper authority. Therefore, the individual who discovers or causes a nonconformance has the responsibility to stop work and report the problem to a supervisor.

Supervisors should be alert for any number of reasons workers deviate from requirements. For example, workers might not understand a specification or lack the skills necessary to meet a given requirement. At other times, there might not be sufficient time to plan for and procure parts or to replace defective equipment resulting in a worker making emergency repairs or modifications to equipment that effects the operation of the equipment. Work should be stopped until the deficient condition is corrected or a modification to the requirement is approved by the proper authority. However, before modifying the requirement, every effort should be made to correct the problem.

The quality monitoring (QA/QC) system should have a mechanism, (e.g., a nonconformance report or deficiency notice) that formally documents the nonconformance, root cause analysis, corrective actions, and approved departures.

2.2.4 Blind Seeding

"Blind seeding" is a QC process in which the QA or QC personnel intentionally emplace UXO/DMM-like objects in the MR project production area to test and validate the UXO/DMM detection process. The emplaced objects are called "seed items" or "blind seeds." The validity of blind seeding as a QA/QC tool is based on the assumption that seed items will accurately mimic actual UXO or DMM expected to be found in the production area. If the MR production team detects the blind seeds, QA/QC personnel assume the UXO/DMM detection procedures are working as planned. On the other hand, if the MR production team fails to find a blind seed, the detection process is either inadequate or being implemented inadequately.

Although standard procedures for blind seeding have not been established or universally accepted by the MR industry, the process—like all MR processes—should be planned, implemented, and documented following the principles and techniques outlined in this document for process development. The planning process for the blind seeding program should produce a plan that describes, in detail, the following:

- Who is responsible for managing the blind seeding program? (frequently the UXO QC Manager)
- Who will emplace the blind seeds in the production survey area? (i.e., QC personnel working under the direction of the UXO QC manager and not part of the production survey work)
- What objects will be used as the blind seeds? (either actual inert ordnance or surrogate metal objects of the same size, material, and shape that duplicate the actual UXO/DMM expected at the site)
- At what depth and orientation will the blind seeds be emplaced? (within the range at which UXO/DMM are expected to be found on the project down to the maximum depth of detection)

- What quantity of blind seeds will be emplaced to ensure that failures in the detection process are promptly discovered? (frequently expressed as a number of blind seeds per survey grid or group of grids)
- What actions will be taken in the event that a blind seed is not found? (usually implementation of the quality nonconformance procedure and a root cause analysis followed by corrective action)

Critical to the success of a blind seeding program is maintaining secrecy from the survey team concerning the number and location of the seeds.

Blind seeding can be used on "mag and dig," digital geophysical mapping (DGM), and even surface removal projects (most surface removal projects require finding UXO/DMM under grass, leaves, and other vegetation that cover the surface of the project site). When used properly, blind seeding may provide the following benefits:

- Regulator confidence is increased because finding the blind seeds demonstrates that the detection program is working adequately under the actual conditions in the survey production area.
- Site workers are continually motivated to implement the detection process properly because they know that blind seeds can be emplaced anywhere within the survey area.
- Failure to find a blind seed can result in process improvements that will prevent missing future blind seeds.

Blind seeding programs are becoming increasingly common on UXO/DMM projects to evaluate the detection process. A well-designed and implemented MR project using blind seeds can serve to increase regulator and stakeholder confidence to a high enough level that post-remediation QC activities such as verification sampling (see section 3.6) may not be necessary for final acceptance of the completed MR project.

2.3 Munitions Response Process Overview

The goal of MR projects is the identification and removal or destruction of all UXO and DMM hazards from a specified area to a specified depth. The beneficiaries of an MR project must be confident that cleared land is safe for its anticipated use. The proper application of a process approach to plan and manage an MR project should produce results of verifiable "quality" with sufficient QA/QC documentation for defensible decision making.

The environmental regulator should participate in defining the overall objective of the MR project, concur with key processes necessary to realize the objective, approve process and final product performance requirements, and agree with the QA/QC activities necessary to demonstrate that requirements have been achieved.

In a process approach to planning and implementing an MR project, QA/QC activities are identified, implemented, and assessed through the natural work flow of the MR project. Some of the processes that make up an MR project are as follows:

- vegetation clearance

- surface removal
- geophysical prove-out (GPO)
- geophysical investigation
  - DGM
  - analog or "mag and dig" investigation
- anomaly resolution
- verification sampling

The use of flowcharts is recommended to help understand and visually depict key steps of each process. A procedure flowchart maps the flow of documents or data; a process flowchart maps the sequence and interaction of related work steps or activities of the MR. Initially, a single flowchart should be developed for the entire MR project. While such a document will be rather abstract, it will help show how processes are interrelated and integrated. Individual flowcharts should also be developed for each process and used to describe how the process should be performed. Figure 2-1 demonstrates a simple flowchart for the vegetation clearance process.

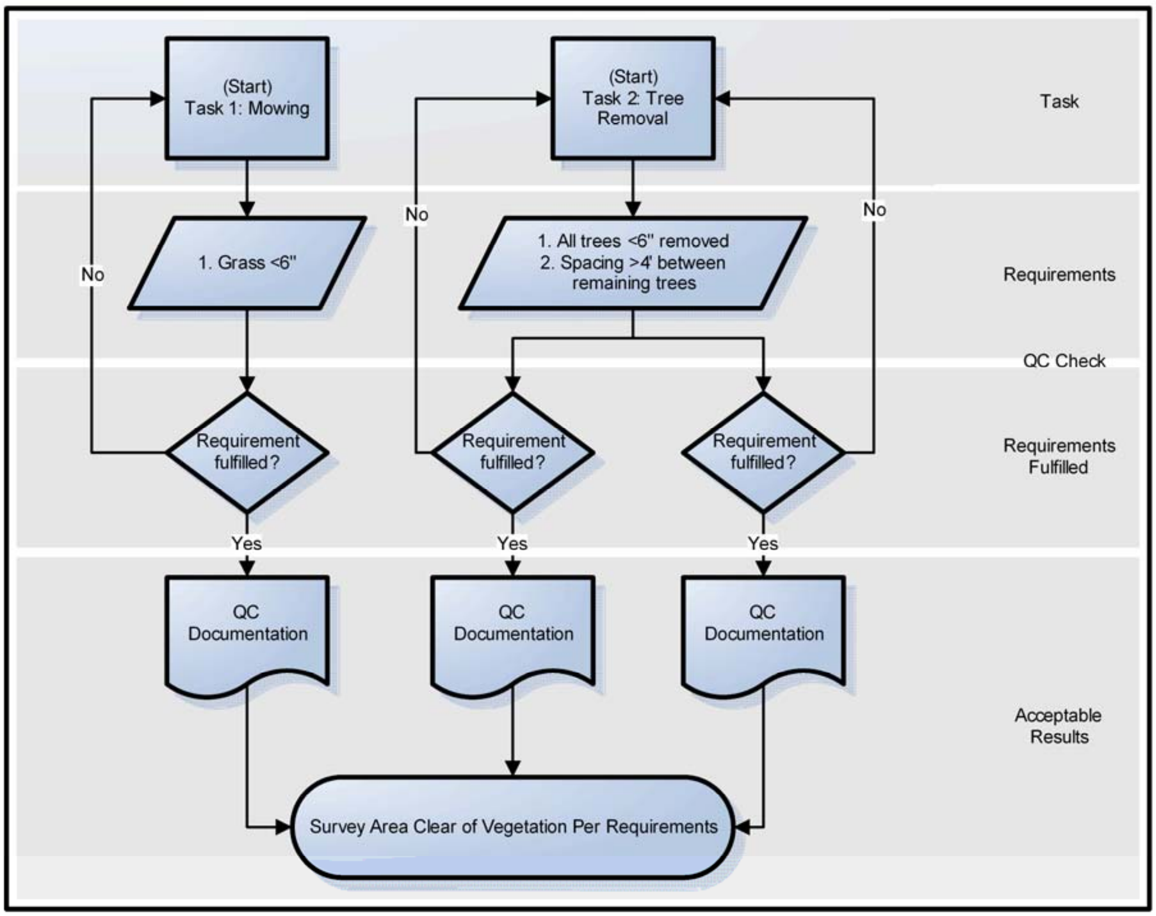

Figure 2-1. A simple flowchart for representing the vegetation clearance process.

In general, each MR process should contain the following elements:

- **purpose/objective**: define the objective or purpose of the process

- **inputs**: What, when, and from what source? (Note: Inputs should also have and meet predetermined requirements.)
- **resources and methods**: With what people, materials, and equipment? How performed? (procedures and instructions)
- **requirements**: Performance indicators.
- **controls**: How monitored and why?
- **responsibility**: Process owner, etc.
- **outputs**: What is delivered, when, and to whom?
- **documentation:** What documents are required to demonstrate conformance to requirements?

The following paragraphs further define these elements and illustrate the level of planning the environmental regulator should expect to find in each MR process. The examples provided focus primarily on vegetation clearance.

Purpose/Objective: The purpose or objective of a process should be clear and concise. The best process descriptions consist of one line. Example: "The purpose of vegetation clearance is to prepare the survey area for DGM."

Inputs: Inputs to a process must be correct. In this particular case, vegetation clearance, accurate location and boundary descriptions of the survey area are critical for the success of this process and the MR as a whole. If the incorrect area is cleared of vegetation, the MR project will fail no matter how well follow-on activities are implemented. Inputs to a process should not be accepted if they do not meet requirements. Example: "A map showing the location and boundary of the survey area. The boundary of the survey area shall form a polygon. Vertices of the polygon shall be identified using survey-grade global positioning system (GPS) equipment."

Resources and Methods: Every process should have a procedure that describes the process and governs and controls how it is carried out. Every procedure should be available for the environmental regulator to review. Typical resource information in a work plan can include size of the work crew, identification of supervisors, and identification of the equipment selected to perform each task. In the case of the vegetation clearance process, the work plan should also describe the methods for how the grasses, brush, and trees will be removed from the production area and how and where the vegetation will be disposed. Example: "Vegetation clearance teams will be composed of five qualified personnel. These personnel will include four UXO Tech I or II and one UXO Tech III, who will act as the team leader. The team will use handheld weed-whackers to cut grass in the production area."

Requirements: The project team should determine process requirements during MR project planning. Requirements can be qualitative or quantitative. The best requirements are quantitative. Establishing inadequate or poorly defined requirements can compromise both efficiency of the process and the quality of the product. Examples:

- Grass mowing—All grass within the survey area shall be mowed to a height less than 6 inches from the ground (to allow visual inspection of the site surface).
- Tree removal—All trees less than 6 inches in diameter shall be removed from the production area (to allow for free movement of the DGM teams).

- Open space—The distance between the trees remaining in the production area shall be greater than 4 feet (to allow for free movement of the DGM teams).

See section 4.2 for more examples of how performance requirements can affect quality.

Controls: Once the project team develops performance requirements for the process, QA/QC activities must be developed to monitor the process and check the product. The QA/QC plan should specify requirements, inspection points, monitoring frequency, monitoring methods, responsible personnel, and the required documentation. QA activities (i.e., presence of standard operating procedures [SOPs], tool inspections, review of personnel training records and QC documents, etc.), and QC activities (testing, measuring) should be conducted during the performance of the activity at designated inspection points and on a predetermined schedule to verify that outputs from that activity will meet or exceed requirements. For some inspection points, this verification may involve visual observation and confirmation that an activity has met requirements. For others, it may involve sampling and analyzing data from the inspection point. An example QC check is, "Measure the height of the grass daily and monitor diameter and spacing of the remaining trees to verify conformance to requirements."

A "QC matrix" is often used to display this information for each process. The QC matrix can serve as the basis for the inspection program for the field QC personnel. Table 2-1 provides an example QC matrix.

Responsibility: Each process should have an identified manager. This manager will be responsible for the safe and successful completion of the process assigned and for correcting any deficiencies discovered during the process or in the final product.

Outputs: The output for each process should be described in the final planning document (i.e., QAPP). For the vegetation clearance process, example outputs are as follows:

- The survey area is free of vegetation per requirements.
- Vegetation clearance is completed within one week of the start of the geophysical survey (since the grass will grow back, the vegetation clearance must be timed to the start of the geophysical survey).
- The customer (geophysics supervisor) accepts the output.

In this example, the geophysics supervisor is identified as the customer or end user of the vegetation clearance process. As the customer, his input was necessary to define the requirements for vegetation clearance because the requirements for vegetation clearance must be adequate to support the follow-on work by the geophysics teams. If the vegetation clearance is inadequate for some reason, the process will fail, and the QA/QC specialist must conduct a root cause analysis to determine why and implement a corrective action.

Table 2-1. Example QC matrix

Process and manager	Inspection point	Requirement	Reference	QC action	Monitoring frequency[a]	Possible corrective actions[b]
Process: Vegetation clearance **Manager:** Vegetation clearance team supervisors	Height of remaining grass	Grass not taller than 6 inches	SOP 1	Measure grass height	Prior to start of analog geophysics	Direct vegetation supervisor to remow the area
	Diameter of remaining trees	Diameter of remaining trees larger than 6 inches		Measure tree diameter	Prior to start of analog geophysics	Direct vegetation supervisor to remove trees smaller than 6 inches from the area
	Open space	Spacing between trees not less than 4 feet		Measure spacing between trees	Prior to start of analog geophysics	Remove additional trees; submit field change request to modify the geophysical process to conform to existing conditions
Process: Analog geophysics (mag and flag) **Manager:** Analog geophysics supervisor	Instrument Test Strip (ITS)	Installed in accordance with work plan (type and number of items, depth of placement, etc.)	SOP 2	Verify ITS is installed in accordance with the work plan and SOP 2	Once at start of project	Reconstruct ITS in accordance with appropriate planning documents; submit a field change request to document changes to the ITS
	Daily instrument checks at ITS	Operators locate all items within the ITS using handheld geophysical instrument		Verify performance of each instrument and operator through the ITS	Initial and daily for each UXO technician	Repair or replace defective instrument; additional training for UXO technician
	Blind seed items	Emplace at least one blind seed per grid		Ensure blind seeds are placed at required rate and recorded in project database	Once at start of project	Place additional blind seeds; ensure blind seed location, depth, and type are recorded in the project database
	Grid coverage	Each grid is divided into individual 5-foot lanes; each UXO technician sweeps the entire lane assigned		Observe grid construction and analog geophysics operations	Once weekly per UXO technician	Additional training for UXO technician; better delineation of search lanes within grid

Process and manager	Inspection point	Requirement	Reference	QC action	Monitoring frequency[a]	Possible corrective actions[b]
Process: Intrusive investigation **Manager**: Excavation team supervisor	Grid completion	Remove all UXO/DMM and any metal objects of size/mass similar to the UXO/DMM of interest from the grid (See Note *c* for explanation of removal requirements)	SOP 3	Randomly select 10% of each grid for resurvey; resurvey and excavate any identified anomalies; if an item is identified that is UXO/DMM or of size/mass similar to the UXO/DMM of interest, require corrective action	At completion of each grid	Resurvey entire grid and then resubmit for QC
	Blind seed items	Successfully locate and remove 100% of seeded items		Monitor excavation results	At completion of each grid	Resurvey entire grid and then resubmit for QC

Note: This table provides examples of QC inspection points for three processes (vegetation clearance, analog geophysics, and intrusive investigation). These examples are intended not to be all-inclusive for these processes, but only to demonstrate inspection points that can be identified for these processes. A similar table is often included in the work plan or the MR UFP-QAPP as Worksheet 35 (see section 4.5 for further discussion of the MR UFP-QAPP).

[a] Monitoring frequency: It is important to note that on many projects multiple individuals or teams may be conducting an activity concurrently. Therefore specifying a monitoring frequency for the overall project may not be adequate. In these cases the monitoring frequency needs to be specified for each individual/team, for example, “Once weekly per UXO technician.”

[b] Prior to implementing a possible corrective action, an evaluation of the root cause of the QC deficiency shall be implemented to identify the cause of the deficiency and identify the appropriate corrective action. This root cause analysis shall be documented in the project database. This column presents possible corrective actions, but the actual corrective action taken will result from a detailed analysis of the root cause of the identified QC deficiency.

[c] Removal requirements should be specified in the work plan and should include the munition of interest and any piece of scrap metal that is of size/mass similar to the UXO/DMM expected to be on the site. Items with a similar size/mass to the munition of interest are specified as these items would have a similar geophysical signature as the UXO/DMM of interest and would be indistinguishable from munition items using geophysical sensors.

Documentation: Process documents take many forms: daily activity reports, QC inspection reports, process completion checklists, or even pictures and videos. Each project team must determine which format(s) will meet its needs best and adequately document the conformance to project requirements. Immediately after a task is completed, each process manager and assigned QA/QC specialist should review QA/QC documentation to ensure it is complete, signed, and correct.

Final reporting requirements for MR projects typically include an after-action report (AAR) that includes a complete summary of project QC and QA activities and should include copies of inspection forms and other completed QA/QC documentation. These documents, when complete, should be able to stand on their own as a record of adherence to procedures and quality requirements.

There are many tools and methods that are used to document quality in MR projects. Various elements can be captured in custom software packages, spreadsheets, handheld computers that are tied to a project-specific database, or on paper forms. There are other examples, such as proprietary systems and the U.S. Navy's Automated Quality Assessment Program System (AQAPS, Naval Facilities Engineering Command 2005).

3. MUNITIONS RESPONSE PROJECT PROCESSES

This section provides an overview of the most common MR processes. The order in which the processes are presented is intended to be approximate and depends on project objectives and site conditions. These processes may occur in a different sequence, or some may not be required. MR processes covered in this section include the following:

- vegetation clearance
- surface removal
- GPO
- geophysical investigation
  - DGM
  - analog or "mag and dig" investigation
- anomaly resolution
- verification sampling

Explosive Safety Submissions (ESS)

Before any intrusive operations can begin, the project team must obtain approval of the ESS. The ESS is a document that, when required (see DOD 6055.09-STD, "DOD Ammunition and Explosives Safety Standards," paragraph C12.5.2), ensures the project complies with DOD explosives safety policy. It details the procedures the project will follow to ensure the protection of site workers and the public. ESS approval must be obtained from the DOD component and DOD Explosives Safety Board.

This section provides a description of each process, the tasks that are typically performed, key factors to consider when planning each MR process, and QC checks to monitor the process and evaluate the resulting product. The project team must develop and agree on the requirements for key processes before the MR field activities begin. Because requirements are project specific, requirements are presented in this section only as examples or to illustrate a concept. Requirements are developed to define, in no uncertain terms, the standard for a completed process or MR project.

3.1 Vegetation Clearance

The purpose of vegetation clearance is to prepare the project site for the safe and effective implementation of follow-on MR processes. While vegetation clearance may appear relatively straightforward, inadequate preparation of the MR site may make the implementation of follow-on processes less effective and possibly more hazardous due to poor surface visibility. Examples of some follow-on processes that may depend on adequate vegetation clearance are surface removal and analog or DGM survey of the work area.

3.1.1 Vegetation Clearance Tasks

Vegetation clearance on an MR site may range from minor grass cutting and limb trimming to the total removal of all vegetation by controlled burning or deforestation. Specific decisions regarding clearance method are often influenced by munition sensitivity, terrain, impacts of disturbance on the landscape, presence of threatened or endangered species, cultural features, current or reasonably anticipated land use, and available technology. Common tasks include the following:

- grass mowing
- limb trimming
- tree removal
- mulching
- controlled burning
- hydraulic ax deforestation
- disposal of logs, stumps, and mulch

The requirements for vegetation clearance tasks must be tailored to meet the needs of follow-on MR processes. Therefore, a clear understanding of process sequencing and customer needs is necessary to develop the appropriate requirements for this process.

Vegetation clearance operations at the former Vieques Naval Training Range, Puerto Rico.

The work plan should contain specifications for the final vegetation clearance that can be inspected by QA/QC personnel. For example, “No trees smaller than 6 inches in diameter will remain on site,” “No mulch deeper than 4 inches will remain on the ground surface,” or “At least 80% of the ground surface must be free of vegetation and visible for inspection.” This specification should be determined by the project technical managers and based on what is necessary to support follow-on MR processes.

3.1.2 Key Factors to Consider During Vegetation Clearance

The following should be considered during planning of the vegetation clearance process:

- how the production area will be identified
- what amount of vegetation clearance is required to allow follow-on MR processes to be performed

- what equipment will be used to clear vegetation
- how many acres need to be cleared of vegetation
- type of vegetation to be cleared (e.g., grass, brush, trees, etc.)
- identification of sensitive, threatened, and endangered species habitat
- weather patterns that may affect vegetation clearance
- qualifications of personnel to perform each task
- type and depth of UXO/DMM that is expected based on historical records and field observations
- necessary permits or approvals from land-use authorities
- consideration of how fast the vegetation will regenerate (For example, is there a maximum amount of time during which the follow-on MR processes must be performed to avoid needing to remove the vegetation again?)

3.1.3 Controls: How and Where to Monitor Vegetation Clearance

QA staff should observe and document the work in progress to ensure procedures are followed, including checking documentation that validates the important aspects of the work (e.g., field completion sheets, status maps, etc.). Example QC checks include the following:

- reviewing the work plan to ensure that it provides adequate guidance (i.e., SOPs) to control the individual tasks and produce the desired product
- inspecting the vegetation clearance area to determine whether it is adequately marked
- ensuring that the selected equipment is adequate and appropriate for site conditions
- ensuring that personnel are properly trained and physically capable of performing the work
- observing the process
- inspecting completed areas and measuring the results (e.g., tree diameter) to ensure conformance to requirements

3.2 Surface Removal

Surface removal may have various goals depending on the specific objective of the MR project. For example, a surface removal may be performed to detect, identify, and remove a majority of the UXO, DMM, and metal debris from the surface of the production area to support follow-on processes (e.g., DGM), which result in the final UXO/DMM removal. Another project may use the surface removal process as the final remedial action, which results in a site that is prepared for its future land use. For these reasons, the overall project goals must be carefully considered and understood when designing the surface removal process. Therefore, as with all MR processes, careful planning and management of the surface removal process is required to achieve conformance to requirements.

3.2.1 Surface Removal Tasks

The following tasks are frequently completed during MR surface removal:

- dividing the work area into grids and the grids into search lanes
- employing grid and lane marking systems (e.g., paint, pin flags, ropes, etc.; professional land survey or other preapproved location survey method to mark survey areas)

- UXO specialists walking search lanes and inspecting the ground—either visually or with the aid of geophysical sensors—to detect UXO/DMM and metal scrap on the surface
- removing metal scrap (if required) and marking UXO/DMM with flagging tape or pin flags for later removal
- documenting the results of the surface removal, including UXO/DMM types, number of finds, locations, pounds of scrap, etc.

3.2.2 Key Factors to Consider During Surface Removal

While it may be possible to perform a surface removal using only visual observation, geophysical sensors may be necessary to detect UXO/DMM if vegetation obscures the surface or if the UXO/DMM is difficult to visually distinguish from the surrounding soil. Typically, handheld metal detectors or magnetometers are adequate for this task. If the vegetation is too dense or the search lane spacing is too wide (or both), UXO specialists may have difficulty seeing and inspecting all portions of the search lane, which may result in missed UXO/DMM.

From a regulatory perspective, surface removal work that prepares a site for a follow-on DGM survey does not necessarily have to adhere to the strict QC and monitoring required if the final remedial objective includes follow-on DGM. However, these procedures may be appropriate to ensure the safety of personnel performing the follow-on processes.

Other key factors to consider include the following:

- What must be removed from the surface? Will removal support any follow-on work planned?
- Is the definition of "surface" understood and agreed upon by all parties?
- What equipment and procedures will be used?
- How will nonconforming conditions be addressed?
- What data must be recorded to document the results of the surface removal?
- Will blind seeding be used and, if so, how?

Blind seeding is the process of placing surrogate UXO or DMM in the surface removal area to test survey procedures (see section 2.1.1.4). Surrogate items are placed in the production area to see if the Surface Removal Team finds them during planned surface removal operations.

3.2.3 Controls: How and Where to Monitor Surface Removal

Typical activities performed by QA/QC personnel during surface removal include the following:

- Monitor the work in progress to ensure conformance to the work plan (e.g., using the correct marking system for search lanes, etc.).
- Monitor for proper and timely record keeping.
- Monitor instrument functionality tests.
- Ensure proper supervision of the surface removal teams.
- Monitor implementation of a blind seeding program.
- Document the identity of the specific UXO specialists and each lane they searched. Such documentation may appear excessive, but each UXO specialist is a unique "UXO detection system," and the quality of root cause analysis for the nonconformance is greatly enhanced

when the UXO specialist who performed the specific work in a search lane is known. This information might not be necessary if the objective of the surface removal is to prepare the MR site for follow-on DGM. However, this strict level of control may be necessary if the surface removal is the final remedy for the site.

- Monitor the GPS track log to ensure all lanes have been entirely covered by UXO specialists.
- Perform verification sampling of the finished product to ensure conformance to requirements. Verification sampling QC may range from a simple visual site walkover to a highly controlled series of 100% survey lane inspections depending on the objective of the surface removal project.

Metal clutter objects following surface removal process.

3.3 Geophysical Prove-Out

The GPO is performed prior to production geophysical surveys (either DGM or “mag and dig”) to demonstrate the capabilities of the geophysical system on site. The ITRC UXO Team has developed a technical and regulatory document on GPOs, *Geophysical Prove-Outs for Munitions Response Projects* (ITRC 2004), to which the reader should refer for detailed information.

As the MR industry matures, the nature and complexity of GPO is changing. The first GPOs tested the contractor’s ability to use geophysical systems and assess the performance of a given geophysical technology used to detect site-specific UXO or DMM. Through years of tests and evaluations at standardized UXO test sites and hundreds of GPOs performed across the United States, the UXO/DMM geophysical community has developed an understanding of the capabilities of the commonly used geophysical sensors and systems. For a detailed review of the most commonly used geophysical technologies please see *Survey of Munitions Response Technology* (ITRC 2006). At the time that document was written, the MR industry was placing less emphasis on using GPOs to evaluate different geophysical systems. Instead, GPOs were being used to verify that processes and procedures being implemented were appropriate for the site.

Once the project team has determined the objectives of the GPO, the team can develop specific requirements for the GPO. Listed below are examples of common GPO objectives. This list is not exhaustive, and the listed objectives are not applicable to all GPOs. Rather, the list is a synopsis of objectives that are common to the various types of GPOs performed at MR sites.

- Test or evaluate the performance of different geophysical systems under the site-specific conditions for the purpose of selecting the appropriate technology.
- Test the adequacy of the contractor’s geophysical data collection work plan.

- Demonstrate or evaluate the contractor's competence in using the geophysical system(s) under the various site-specific conditions (e.g., terrain, vegetation, cultural obstacles and interferences, geology, etc.).
- Demonstrate the overall capabilities of the geophysical system (i.e., detection depth, sensitivity, etc.).
- Establish initial anomaly selection criteria and background noise level.
- Establish requirements that are specific to the geophysical systems and how they are used to ensure the UXO or DMM of interest are detected.
- Establish data transfer protocol (e.g., file formats, transfer interval, etc.).
- Evaluate how the contractor implements the QA/QC plan.
- Test or evaluate anomaly reacquisition procedures.

3.3.1 GPO Tasks

The GPO has become a vehicle to demonstrate that a particular geophysical system is working properly and producing data that meet the geophysical requirements for a specific MR project. It can also be used to adjust and optimize the geophysical system prior to beginning production geophysics. Figure 3-1 shows the tasks and subtasks that make up a GPO. The four major tasks are design, construction, implementation, and reporting.

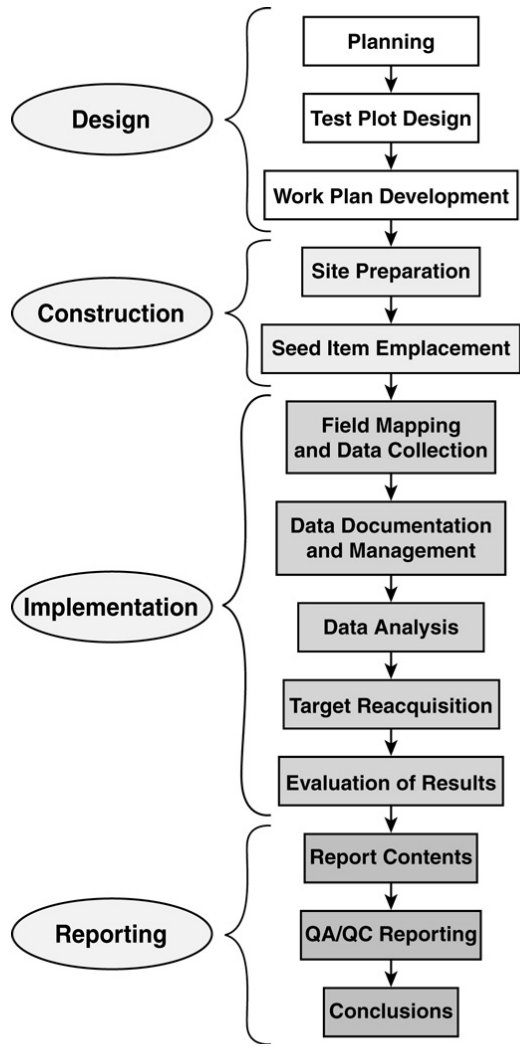

Figure 3-1. Summary of the GPO technical process. (ITRC 2004)

3.3.2 Key Factors to Consider During the GPO

Depending on the objectives of the GPO, one or more of the following key factors for decision making during a GPO is typical:

- What are the appropriate lane spacing, survey speeds, and noise levels to meet project objectives?
- What are the initial anomaly selection criteria and why are they appropriate for the objectives? Are these the same that will be used in production, or do the anomaly selection criteria need to be adjusted?
- What are the requirements that constitute a successful detection?
- What are the overall performance requirements for the contractor being evaluated on the GPO?
- Can a "dig/no dig" criterion be established?
- What is the protocol for analyzing and correcting a nonconformance or failure (i.e., root cause analysis and corrective action)?

The following are examples of factors that are used for decision making during the GPO:

- Were the GPO goals achieved, or are adjustments required to be made to the overall project expectations and objectives because the GPO demonstrated that they cannot be accomplished?
- Can improvements be made to the geophysical process to increase efficiency or effectiveness?
- Does the GPO area adequately represent the characteristics (e.g., terrain, vegetation, geology, etc.) of the production geophysics area?
- Is the geophysical system performing the GPO (the personnel, sensors, navigation, data handling, and processing) the same as will be used for the production geophysical surveys?
- Is there a process for changing field procedures or anomaly selection criteria based on the results of the GPO?

3.3.3 Controls: How and Where to Monitor the GPO

Geophysical Prove-Outs for Munitions Response Projects (ITRC 2004) describes the four phases that are common to most GPOs: design, construction, implementation, and reporting. Each phase and the major tasks in each phase should be carefully monitored to ensure a quality GPO. The planning and construction of the GPO should be completed by an experienced QA or QC team that is separate from the geophysical team performing the production geophysical surveys.

3.3.3.1 Design

The purpose of the design phase is to create a GPO design that assesses the appropriateness of a geophysical detection system or approach to meet MR objectives. For example, if the objective of an MR is to detect and remove all 155 mm UXO/DMM to a depth of 5.6 feet (or 11 times [11×] the diameter) below the surface of the work site, the objective of the GPO should be to confirm that the selected geophysical system can meet this detection requirement under conditions that are very similar to those found in the production geophysical survey area. The GPO design should therefore specify burying a certain number of 155 mm UXO/DMM surrogates at various orientations and depths at least down to 5.6 feet below the surface. The reader is referred to Table 8-3 in EM 1110-1-4009 (USACE 2007), which lists assumptions for the 11× diameter guideline.

Other critical elements of the design include defining how depth to the buried item is measured (common measures include depth to the shallowest burial point or to the center of mass of the item) and defining dimensions or composition of seed items that will be buried to simulate UXO/DMM (if actual inert UXO/DMM is not available). Inert munitions are preferred over simulated seed items as they more accurately reflect the geophysical signatures of the munitions of interest.

3.3.3.2 Construction

QA and QC during the GPO construction phase should be very straightforward. The intent of QA or QC is to ensure and verify that the GPO conforms to the approved design. One method to ensure conformance to requirements is for QA and QC specialists experienced in constructing

GPOs to monitor the construction. QA should also include recording the location, depth, and orientation of the buried blind seed items; photographing each blind seed item prior to burial; and reviewing records and photographs of the items buried, depth, orientation, and number to verify compliance with design specifications. Necessary deviations from the original plan should be approved and accompanied by a reasonable explanation, such as "encountered bedrock before reaching the prescribed depth." Common QC checks include the following:

- verifying that the GPO location meets design specifications for
  - geology and soils
  - cultural interferences
  - terrain conditions
  - vegetation conditions
- verifying that a geophysical background survey was performed prior to seeding
- verifying that burial locations were selected according to the GPO design specifications
- verifying that the number of buried items meets design specifications
- verifying for each planned seed item
  - the nomenclature
  - whether the seed item is inert or simulated
  - the planned and actual depth for the seed item
  - the planned and actual orientation for the seed item
- verifying that the actual seed burial characteristics meet the planned specifications (What are the differences, and do these changes impact any project goals or objectives?)

3.3.3.3 Implementation

Monitoring during the implementation phase will involve QA oversight to ensure that the GPO plan is followed by the GPO construction team. The team constructing the GPO should not be allowed to deviate from the plan without approval. QA should also ensure that personnel involved with GPO construction are not involved with the geophysical team being tested by the GPO.

All personnel and equipment that will be used in the production area of the MR project should be certified through the GPO, including the geophysical equipment, the team members collecting the data, and the geophysicist performing the data analysis and interpretation. The same team certified through the GPO should remain intact throughout the entire MR project. Problems may be encountered later in the MR project if the "A team" is used to perform the GPO but the "B team" is used later on during the MR geophysical investigations.

During the implementation phase of the GPO, QA specialists should observe the implementation of the GPO and review the GPO records to ensure that the QC practices in the GPO conform to those planned for the production area. Listed below are common tasks that may require QC during the GPO and for the production geophysical work.

- <u>Instrument functionality:</u> Basic instrument functionality tests to demonstrate the geophysical systems are operating according to normal expectations. These frequently include the following:

  - static (background) test—monitoring the "background" signal fluctuations without a standard object to ensure the data are within an acceptable range
  - instrument response test—placing a standard object directly under the sensor to ensure that the recorded sensor reading is within acceptable parameters for repeatability
  - cable test—shaking electrical cables to determine whether loose connections cause fluctuations in the recorded data
  - personnel interference test—checking the sensor operators for metal objects on their person that can interfere with sensor
  - repeatability test—collecting repeat geophysical data to evaluate the ability of the instrument to respond consistently and to evaluate the positional accuracy of the data
  - system positioning test—recording the coordinates of a known point to determine whether the computed position is within a certain radius of the known point

- <u>Data collection:</u> QA/QC during data collection may consist of the following inspection points to ensure:
  - implementation of navigation procedures as planned
  - sensor deployment performed as planned, confirming, for example, the following:
    - the sensor orientation with respect to the ground surface (i.e., minimize instrument bounce and maintain horizontal orientation with the ground surface as the operator traverses the GPO site)
    - sensor height above the ground surface conforming to requirements
    - the positioning device rigidly mounted and the offset between the positioning device and the geophysical sensor accurately measured
  - removal of all metal on the operator
  - metal parts on the instrument platform not moving with respect to the actual sensor
  - synchronization between different equipment components (i.e., GPS system and geophysical sensor) to ensure different equipment components are synchronized when collecting data—monitored by timestamp
  - up-to-date equipment maintenance and calibrationed—monitor by checking logbooks and field verification of serial numbers

  QA/QC for the data collection phase above may be reduced to QC checklists for use by the QA specialist. Completed checklists should be signed and become part of the QA record. A checklist may include the following considerations:

  - Are the instruments tested during the GPO the same instruments described in the GPO plan?
  - Are the procedures used in the field to operate the instrument the same as the procedures described in the GPO plan?
  - Are the line spacing, instrument height, and survey speed parameters used during the GPO the same as those identified in the GPO plan?

- <u>Processing:</u> If the GPO is being done for a DGM survey, after collecting the data, the data are processed, analyzed, and interpreted by the geophysicist. QA for this process may consist of reviewing the QC documentation checklists for completeness and accuracy. Common checks during the data processing, analysis, and interpretation stage include the following:

- position accuracy and precision as defined in the GPO work plan (e.g., positioning accuracy at known survey monument ±25 cm)
- line and station density
- common sensor corrections (i.e., system positioning, data collection)
- detection of known control points (e.g., metal nails at grid corners) and seed items detected to specifications
- deviation in track path around aboveground surface features
- color-coded images and site maps output as prescribed in work plan; raw and processed geophysical data supplied in correct format(s)

Not all of the QC checks described here are appropriate for all geophysical systems. For instrument function tests, the actual values for some tests may not be known, and the initial tests performed at the start of GPO will form the baseline for subsequent tests. One example is the standard response test in which a piece of metal, commonly a steel bolt, is emplaced in a wood 2×4 so that it can be placed in the same position consistently on an EM61 coil. The instrument readings over this object may not be known at the onset of the GPO, but instrument functionality is demonstrated by repeating this response during subsequent tests.

3.3.3.4 Reporting

The reporting phase of the GPO process involves the development, review, and analysis of the GPO report. The GPO report should describe all aspects of the GPO design and the data collected. The report should also describe how the data were processed, analyzed, and interpreted. If the analysis and interpretation procedures deviate from those planned, the report should explain how the new approaches benefit the geophysical program and improve the results. Lastly, the GPO report should clearly define the requirements that need to be monitored and achieved throughout the duration of the full production work.

Geophysical prove-out target scoring.

3.4 Geophysical Investigation

Operators performing a man-portable DGM survey during an MR project on Adak, Alaska.

Geophysical investigation refers to the use of a geophysical system to detect and locate UXO/DMM. Geophysical systems are composed of analog or DGM sensors, positioning and navigation tools, deployment platforms, and data management and interpretation processes and procedures. Instrument operators are also considered components of the geophysical system when their tasks can affect the geophysical system's performance.

There are two main geophysical processes: DGM and analog. DGM systems consist of a geophysical sensor, data recorder, and navigation equipment that georeferences the geophysical measurements. DGM data are recorded and stored so that they can be processed and interpreted either in real time, near-real time, or any later time after the data collection is complete. Analog geophysical systems use sensors that produce signals to the operator (usually an audible output, a meter deflection, a numeric output, or a combination of these), which are immediately interpreted by the instrument operator. Upon recognizing the appropriate sensor output, the instrument operator usually marks the location of the detected subsurface object with a pin flag or spray paint. QC for DGM and analog geophysical systems will be discussed separately in the following two sections.

3.4.1 Digital Geophysical Mapping

A DGM system is a collection of instruments, processes, and procedures that are integrated into a system used to detect metallic objects, such as UXO/DMM, and record their location for later investigation. The geophysical data are collected from the output of a geophysical sensor (usually a magnetometer or an active electromagnetic sensor), and the navigation data are collected from the output of the navigation system selected for use, for example a differential GPS (DGPS), an acoustic positioning system or laser rangefinder, or a grid-based fiducial navigation system. See *Survey of Munitions Response Technologies* (ITRC 2006) for a more detailed discussion of the functioning of DGM and positioning systems.

> **Fiducial Positioning**
>
> Fiducial positioning is a method of manually placing electronic markers that indicate fixed locations within a set of recorded geophysical data. For more information on fiducial positioning, see section 3.3.3.3 of *Survey of Munitions Response Technologies* (ITRC 2006).

It should be understood that geophysics is a specialty science and applying geophysical theories and DGM process to the detection of UXO/DMM is a distinct specialty within the geophysics industry. It is unlikely that most state regulators will have the scientific and technical background to completely understand all of the detailed decisions that are involved with planning and implementing a DGM project. This does not mean, however, that DGM should be considered a "black box" technology that produces usable data automatically. Professional geophysicists planning and implementing the DGM project make technical decisions and perform numerous operations at the project site and remote computer work stations that require professional judgment. Inadequate quality in any of the DGM system's components and/or processes can result in a DGM product that is inadequate to meet the project's requirements. Therefore, it is critical for the regulatory community to be familiar with the QC processes and requirements for the DGM investigation as these elements ensure the success of the DGM program.

3.4.1.1 DGM Tasks

Tasks that are common to most DGM projects include the following:

- collecting and recording geophysical sensor and position data
- data processing, analysis, and interpretation to identify potential UXO/DMM
- creating a "dig list" with adequate information to allow the dig team to reacquire the anomaly location and investigate the anomaly
- reporting the results of the DGM activities

3.4.1.2 Key Factors to Consider for DGM

Some of the key factors to consider when planning and assessing DGM quality are as follows:

- Was the GPO successful, and are the results of the GPO being used to maximize the effectiveness of the DGM program?
- Are the important requirements of the DGM project, including detection depth, anomaly selection criteria, area coverage requirements, and survey area boundaries, adequately specified in the project work plan?
- What are the DQOs for the DGM data, and what is the mechanism for checking and documenting each?
- What equipment and personnel resources will be used?
- What protocol will be used to implement and document changes to the approved DGM work plan?
- Will blind seed items be used as a QC tool to demonstrate the effectiveness of the DGM project? If so, what are the specifications for the emplacement of the blind seeds?
- Does the natural site background noise prevent detection of the UXO/DMM at the necessary depths?
- Is the same system (i.e., equipment, personnel, and procedures) used for the GPO being used for the production DGM surveys?

3.4.1.3 Controls for DGM: How and Where to Monitor

Key DGM tasks that require QC monitoring and oversight are as follows:

- detection equipment functionality tests

- positioning equipment functionality tests
- DGM deployment
- data processing, data interpretation, and anomaly selection
- feedback process

The following text describes common QC measures for these five tasks.

3.4.1.4 Common Quality Control Measures for DGM

Detection Equipment Functionality Tests—There are two types of QC testing used to ensure the proper functioning of the geophysical sensor: scheduled and random.

Scheduled function tests are usually performed by the team of technicians performing the DGM surveys and are performed and recorded in accordance with approved procedures contained in the work plan, QAPP, or SOPs. Examples of common scheduled function tests include the following (section 3.3.3.3 provides a more detailed description of these function tests):

- background test
- instrument response test
- cable test
- personnel interference test
- repeatability test
- system positioning test

QA of the function tests usually involves checking to ensure that the tests are performed and documented as required by the approved plan. It is also appropriate for QA personnel to periodically observe performance of the sensor function tests.

Random function tests are performed using blind seeding. Under a blind seeding program, seed items are emplaced in the production area. Whether or not the seed items are detected and identified for intrusive investigation is an excellent demonstration of the adequate functioning of the geophysical system. See section 2.1.1.4 for more information on this important QA tool.

Positioning Equipment Functionality Tests—As with the function tests of the geophysical sensor described above, tests of the positioning equipment can be both scheduled and random. Scheduled positioning function tests are performed for the same reasons and on the same schedule as for the geophysical sensor and frequently include the following:

- recording the position of a known control point to ensure the basic accuracy DQO is being achieved
- repeatedly crossing a test object from different angles to ensure that the geophysical sensor and the positioning system data streams are synchronized

Also, as with the sensor tests, the blind seeding program will demonstrate whether or not the positioning system is operating adequately based on the ability of the resolution team to locate and successfully recover the blind seeds.

DGM Deployment—The deployment of the DGM system should be described in detail in the work plan, QAPP, or SOPs. The following are aspects of deployment of the DGM system that are usually described in the plan:

- the height of the sensor above the ground
- the maximum allowable spacing between sensor transects (the paths back and forth across the production survey area)
- the maximum separation allowable between sensor measurements along each path. (i.e., data collection rate or maximum speed of sensor travel)
- the tolerance for the offset of the positioning system with respect to the geophysical sensor

QC of these requirements for deployment of the DGM system may be accomplished by observing the performance of the DGM teams in the field and/or examining the data that are collected. One way to evaluate digital data (e.g., sensor positioning) is to produce a "track map." By producing a track map, sensor positioning can be evaluated to determine whether maximum line spacing and sample distance meet requirements (see Figure 3-2).

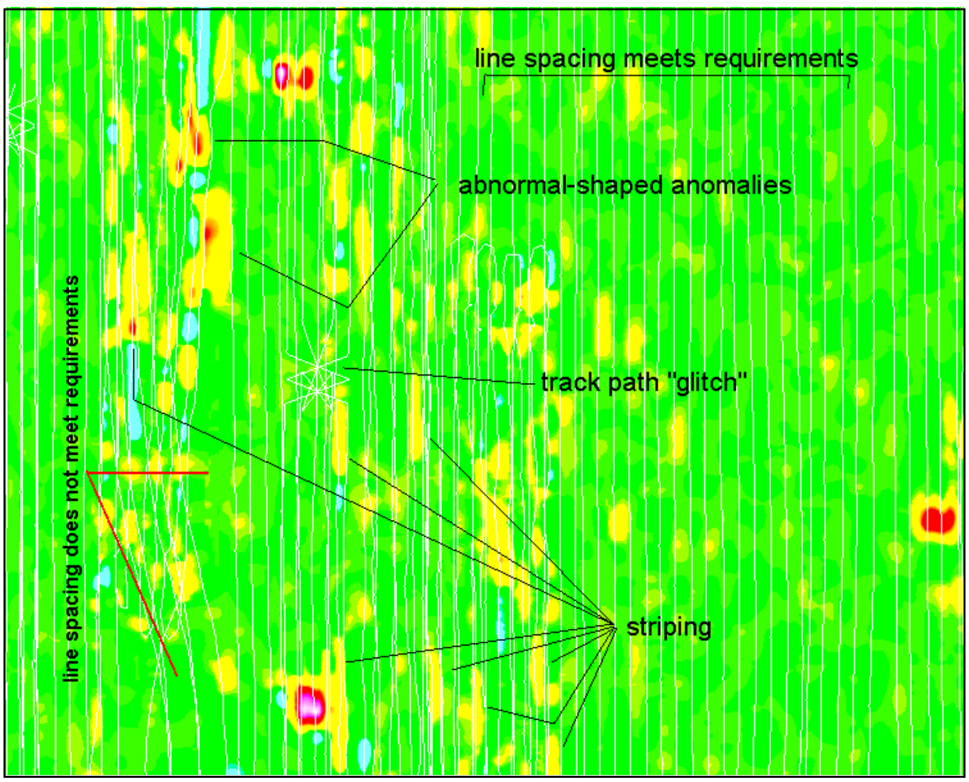

Figure 3-2. EM61 towed-array data.

Line spacing requirements are determined based on the size of UXO/DMM of interest. If line spacing exceeds the requirement, smaller UXO/DMM could be present that may be missed by the sensor. (Note the lack of anomalies in areas where line spacing does not meet requirements.)

The blind seeding program is also valuable as a QC check on DGM system deployment because it demonstrates whether or not the DGM system was being deployed adequately to detect and record the location of the blind seed.

Data Processing, Data Interpretation, and Anomaly Selection—The goal of processing is to accurately identify individual locations within the project site that represent potential UXO/DMM. This process includes use of data processing software, examination of anomaly plots, selection of anomalies for inclusion on the dig sheet, and data file management. For the regulator, the quality of the processing and interpretation processes can often be reduced to the following several checks that address some of the more common types of failures during this process:

- banding (i.e., striations, stripes) coincident with line locations in the processed data
- abnormally shaped anomalies
- general statistics for point-to-point distances between samples, acquisition lines, and average noise levels in "background" areas, used to verify that the final data product meets the project requirements
- signal-to-noise ratios (SNRs) of anomalies in final processed data channels within a certain percentage (usually 2%–5%, depending on amplitude) of the unprocessed data signals

The above checks are important to ensure that potential UXO/DMM items are not missed by the DGM system due to excessive line and/or station spacing and that project funds are not significantly diminished by excavating anomalies that are related to improper data acquisition and/or processing practices.

In addition, the regulatory community should review these other data processing and interpretation products and processes:

- Verify that blind seed items were selected as targets of interest.
- Review documentation for data processing and anomaly selection and ensure that the approved SOP was followed.
- Review logs that track who, when, and how data files were accessed and modified.
- Ensure that the procedures used to back up the DGM information result in no lost or overwritten data.

Numerous computer programs and procedures are used to process and interpret DGM data, some of which are proprietary to the contractor performing the work. The most commonly used DGM data processing program, Oasis Montaj®, contains some elements that were specifically developed in conjunction with DOD for use on MR projects. An example is the QC module that provides automated quality checks of the DGM data and to the processes applied to the data. Regardless of the method used, the work plan, QAPP, or SOPs should describe the QC process for DGM data and the method of documenting that the QC requirements are implemented.

Readers interested in a more detailed review of the quality monitoring aspects for data processing and interpretation are encouraged to review chapter 9 of EM-1110-1-4009 (USACE 2007).

Feedback Process—This phase of the DGM process is an important QC tool wherein experienced geophysicists compare the information from the intrusive investigation to the geophysical data, allowing them to observe the field results from the entire DGM process and determine whether the excavation team is recovering objects similar to those predicted from the DGM data. If the recovered objects are significantly different from those predicted from the DGM data or excessive "no finds" or "hot rocks" are encountered, technical analysis to determine the root cause(s) of this unexpected condition and its effect on the overall quality of the DGM program should be performed and corrective action taken as warranted.

3.4.1.5 Summary of QA and QC for Digital Geophysical Mapping

In summary, state regulator QA of the DGM process frequently consists of ensuring that the QC inspections required by the plans are implemented and documented in accordance with the requirements of the work plan, QAPP, or SOPs. In some cases the state regulator can use a contractor to independently process samples of the "raw" (without modification) DGM data and to compare the results to those achieved by the production contractor. This additional level of oversight QA is sometimes used. However, a QC program implemented by qualified and experienced geophysicists combined with a blind seeding program is usually sufficient to demonstrate adequate quality and compliance with the DQOs.

3.4.2 Analog Geophysics

Analog or "mag and dig" geophysics is a process in which analog geophysical instruments are used to detect anomalies. These anomalies are detected in "real time," generally by an audible or visual signal interpreted by the operator. The anomalies are then marked, typically with a pin flag or spray paint, and each marked anomaly is excavated to determine whether it is UXO/DMM. The terminology "mag and dig" can be misleading since any geophysical sensor, including commonly used analog magnetometers or analog electromagnetic induction (EMI) equipment, can be used to detect the anomaly. Instruments frequently used for DGM (e.g., Geometric G858 magnetometer, Geonics EM61 time domain electromagnetic system) can also be used in analog mode. Other terminology commonly used to describe this process is "mag and flag." These terms refer to the practice of using an analog geophysical instrument to locate an anomaly, mark the location on the ground surface with a pin flag or spray paint, and later excavate the flagged location to determine what is buried there.

Analog Geophysics

Comprehensive reviews of the capabilities and limitations for frequently used handheld EMI sensors used for analog geophysics can be found in *Systematic Test and Evaluation of Metal Detectors, Interim Report Field Trial Mozambique*, European Commission Joint Research Centre Report EUR 21886 EN (2005).

"Mag and dig" differs from DGM in that no digital data are recorded and analyzed. As a result, detected subsurface anomalies are excavated to determine whether they are UXO/DMM. "Mag and dig" can also be used on a site with heavy UXO/DMM and metal debris to achieve a "preliminary removal" of a majority of the UXO/DMM and clutter prior to employing DGM as part of the final removal or remedial action. Because no digital data are recorded during "mag and dig" and there is no record of the interpretation performed by the operator, it is much more difficult to perform QC of those tasks. Other methods, such as observation of field teams, a blind seeding program, or instrument function checks should be employed.

3.4.2.1 Tasks for "Mag and Dig"

Analog geophysics is performed by dividing the work area into search lanes approximately 5 feet wide. Each lane is surveyed by a technician using an analog geophysical sensor. The sensor is swung back and forth across the search lane, covering the entire area of the search lane with the sensor, as the technician slowly walks forward. An analog signal, usually an audible noise, indicates a detection of a metal object and prompts the technician to place a marker, usually a pin flag, in the ground to mark the location of the anomaly for subsequent excavation.

Equipment used to perform analog geophysics consists mostly of lower-cost, handheld magnetometers and EMI devices. The personnel used to perform analog geophysics are usually lower- or entry-level "sweep personnel" or entry-level UXO technicians who receive on-the-job training in the operation of the geophysical sensors and are usually supervised by more senior UXO technicians. For more details on DOD personnel qualifications requirements, see *Minimum Qualifications for Unexploded Ordnance (UXO) Technicians and Personnel* (DOD 2004b).

3.4.2.2 Key Factors to Consider for "Mag and Dig"

- What are the procedural requirements, and what is the mechanism for checking and documenting each (e.g., lane spacing and control, instrument function checks)?
- If decisions resulting from the GPO need to be modified based on unanticipated site characteristics, what protocol will be used to implement and document changes? Is there a need to validate changes in the GPO?
- How much and what kind of blind seeding will be used? What are the criteria for success? Is there a protocol for failure analysis and corrective action?

3.4.2.3 Controls: How and When to Monitor "Mag and Dig"

When analog geophysics is used for the final clearance, QA and QC personnel must frequently monitor the process to establish a high degree of confidence in the removal of UXO/DMM due to uncontrollable variables inherent to analog detection systems. For example, unlike DGM, analog geophysics does not produce a record of the survey which QA and QC personnel may evaluate for completeness of coverage. In addition, each technician clearing a search lane should be considered an individual geophysical system that needs to be monitored to ensure its work product conforms to requirements. For example, each technician has a different level of hearing acuity and different sweep patterns and habits. For this reason, careful monitoring for compliance with the procedures in the work plan is necessary to control the numerous variables inherent to the analog geophysical process.

QC monitoring can occur during the following operations:

- personnel selection to ensure that only qualified site workers are used
- personnel training to ensure that only properly trained workers are used
- geophysical instrument checks on at least a daily basis to ensure each operator/sensor pair is capable of meeting the project performance requirements
- monitoring work performance to ensure work plan–specified procedures are being followed

Because of the many variables involved in performing analog geophysics, QC monitoring often takes place multiple times each work day and may even be performed continuously by placing a QC observer with each analog survey team on a full-time basis.

3.4.2.4 Common QC Measures for "Mag and Dig"

Personnel selection, training, and geophysical instrument checks can be monitored by QC personnel or, at a minimum, documented in writing to be inspected by QC personnel. Observation of the performance of the work should be documented in daily QC reports.

Implementation of a blind seeding program, as discussed in section 2.1.1.4, has proven to be an effective method to demonstrate that the project objectives are being met and to increase confidence in the final work product. The blind seeds should be detected by the technicians performing the analog geophysics and recovered by the dig team. Failure to detect the blind seeds is an indication that there is a quality deficiency in the system that should be investigated and corrected. Testing each operator's proficiency—if necessary or desired—will require multiple blind seeds as well as statistics to help determine how many seeds are needed to test each operator the desired number of times.

3.5 Anomaly Resolution

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 or the clearance depth is reached. There are two key aspects to anomaly resolution, anomaly reacquisition and anomaly excavation, which also include reporting dig results (USACE 2007). Anomaly resolution occurs once the DGM process has produced a map of the site or the analog (mag and dig) geophysics process is complete and subsurface anomalies are marked with pin flags or other marking methods. The UXO technicians navigate to the anomaly location (DGM) or visually locate each pin flag (mag and dig) to excavate the anomaly. The anomaly is excavated and the results of the dig (item identification, depth, orientation, etc.) are recorded. The excavated item is identified and segregated for proper treatment/disposal and is removed and properly disposed of. The excavation is backfilled, and the site is restored to the specifications required in the approved project plans.

3.5.1 Anomaly Resolution Tasks

The anomaly resolution process consists of the following three major tasks:

- anomaly reacquisition
  - Navigate to the anomaly location.
  - Confirm the presence of the anomaly within the project-defined search radius (as defined in the DQO).
- anomaly excavation
  - Excavate the anomaly.
  - Document the findings.
- post-excavation activities

- UXO/DMM disposal
- handling of material potentially presenting an explosive hazard (MPPEH)
- site restoration

For DGM, a combination team of geophysicists and UXO technicians frequently perform resolution of anomalies. The geophysicists who collected the data are usually responsible for relocating the anomalies, and the UXO technicians provide general safety support. Anomaly reacquisition is a critical element of DGM systems because this task must physically match anomalies on dig lists with their sources. This step 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 (USACE 2007). Reacquisition of anomalies is a major point of potential quality error in DGM systems. Care should be taken to ensure that navigation systems and equipment procedures are adequate, especially with respect to the sensor technology used during the DGM phase and that proposed for anomaly reacquisition. Problems can arise when different sensor technologies are used for the DGM and reacquisition processes. The capabilities of the systems may differ greatly, and using a different system does not permit verification of anomaly amplitude.

Once the anomaly is located and its exact position is refined, the UXO excavation team can excavate the anomaly. This step is performed using SOPs that the qualified UXO technicians should have learned during their training and should be available for review.

Once the anomaly is excavated, the material removed must be positively identified. Until the item has been positively identified, it is considered to be MPPEH, which must be managed and documented in accordance with DOD Instruction 4160.21-M-1, *Defense Demilitarization Manual* (DOD 1991), and DOD Instruction 4140.62, *Management and Disposition of Material Potentially Presenting an Explosive Hazard (MPPEH)* (DOD 2004a). The latter reference is the DOD instruction to prevent accidents involving explosives in scrap metal. Additional guidance includes EM 1110-1-4009 (USACE 2007) for USACE projects or OP 5 (Department of Navy 2007) for Navy projects.

DOD instructions mandate that all MPPEH receive a 100% inspection and a 100% reinspection by at least two qualified personnel who must concur on the identification of the material (i.e., UXO/DMM, munitions debris, range-related debris, or cultural debris) to prevent mishandling and accidental on-site detonation. Once the item is positively identified, a decision will be made regarding the management of the material. If the item is determined to be hazardous (e.g., UXO or DMM) the decision will be made whether to “blow in place” (BIP) or move the item to storage for subsequent disposal.

Munitions debris and range-related debris are containerized, sealed under chain-of-custody procedures, and delivered to an approved scrap processor for smelting. Other materials generated at the project site, including solid waste, will be managed in accordance with the work plan.

3.5.2 Key Factors for Decision Making for Anomaly Resolution

Key factors for decision making for anomaly resolution are as follows:

- What procedures and equipment will be used to navigate back to and relocate the anomaly? They should be consistent with the equipment or systems used to originally detect the anomaly.
- What criteria will the resolution team use to determine that they have reacquired the correct anomaly?
- What field procedures are in place to determine when a hole is “cleared?”
- What are the procedures to inspect and categorize the excavated item?
- How will UXO/DMM be handled and disposed of (BIP, consolidated detonation, temporary storage and later disposal)?
- For DGM, does the actual object recovered meet the expectations of the geophysicists based on the geophysical data (see discussion of feedback process in section 3.4.1.4)?
- Have all dig-list anomalies (meeting anomaly selection criteria) been investigated?
- Has all potentially hazardous material been identified, segregated, inspected, and properly handled?
- Has MPPEH (UXO, DMM, and other materials) been handled appropriately as described in section 3.5.3?

3.5.3 Controls: How and Where to Monitor Anomaly Resolution

Following removal or disposal of the MPPEH, it is recommended to have QC personnel inspect the excavation hole to ensure that no items of interest remain. It is possible to have more than one UXO/DMM located at an anomaly site, and shallow munitions debris may mask deeper items. This QC check will help to ensure that no UXO/DMM remain in the excavation.

Navigation or anomaly positioning errors may result in the excavation team excavating the incorrect anomaly. The geophysicists should be able to identify this error if the QC program requires them to compare the results of the anomaly excavations with the original geophysical data to determine whether or not the excavated object matches the expected size and depth from the geophysical data (this control is covered in more detail in section 3.4.1.4). If not, a root cause analysis can be performed, and trends may become apparent if numerous anomalies do not match the objects excavated. Possible causes of this error are as follows:

- Navigation, positioning, or procedural errors caused the excavation team to dig in the incorrect location.
- The excavation team performing the excavation dug up the first item encountered, stopped, and did not retrieve the intended item.

Monitoring of UXO/DMM and MPPEH disposal is important because it is a critical interface between the project site and the scrap disposal operation, which is usually located off site in the community. Improperly classified “scrap” containing explosives delivered to recycling facilities has resulted in injuries and deaths. This process must be tightly controlled, monitored, and documented to prevent these accidents in the future. Figure 3-2 presents a flow chart graphically demonstrating the procedures for inspecting and categorizing excavated items. As an example of this level of control, see chapter 14 of EM 1110-1-4009 (USACE 2007) for a description of the procedures for MPPEH inspection, certification, and disposition, including required QC checks. Navy requirements for MPPEH are discussed in OP 5 (Department of Navy 2007).

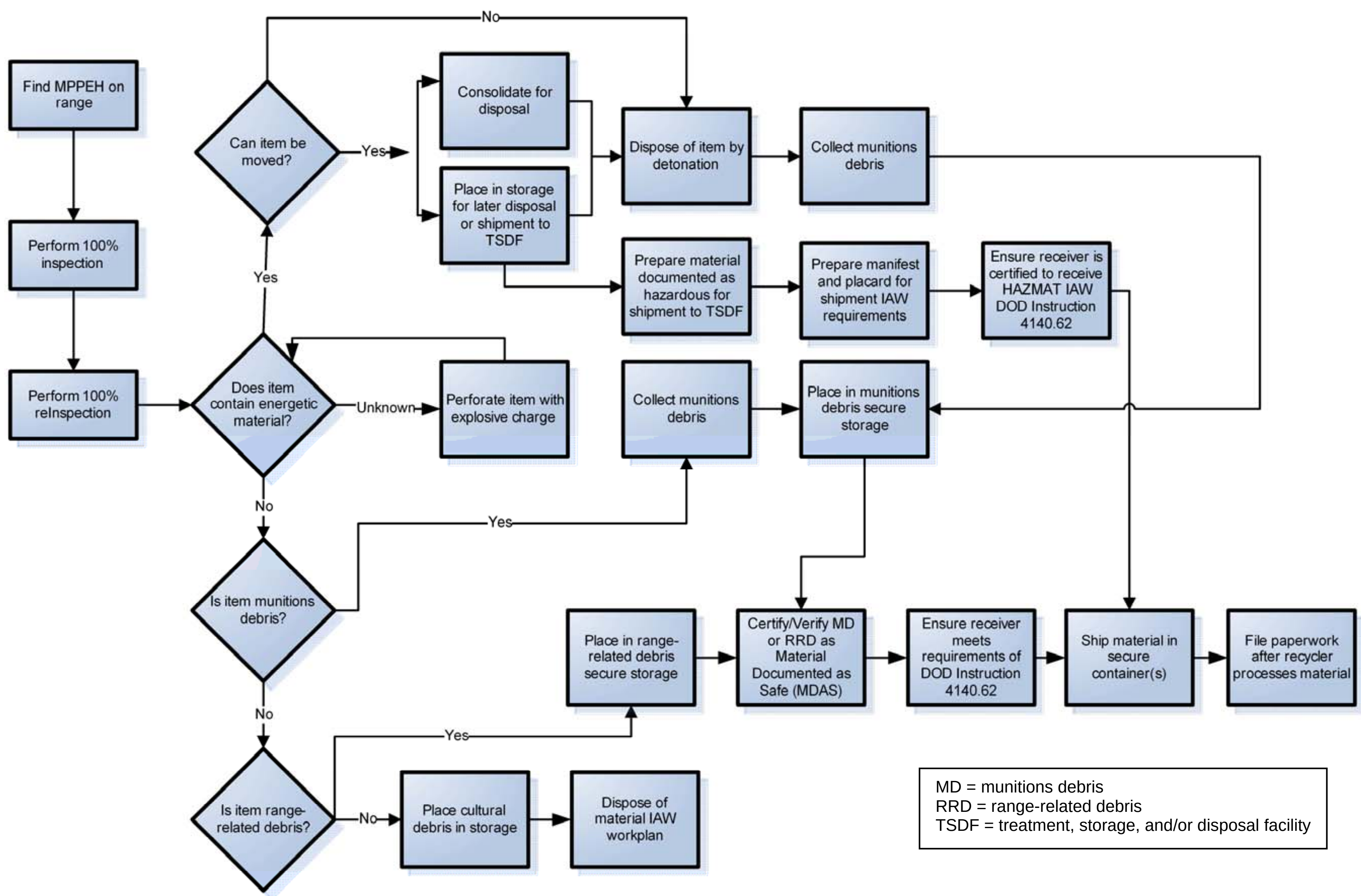

Figure 3-3. Procedures for inspecting and categorizing excavated items.

3.5.4 Common Quality Control Measures for Anomaly Resolution

The following are ways to measure the quality of the anomaly resolution process:

- Excavated locations (all or a percentage) should be checked by QC personnel to verify that they meet the project criteria using detection tools having the same detection capabilities as the original geophysical system. Areas with geophysical responses above the anomaly selection criteria remaining should be documented and explained.
- Blind seeds emplaced in the search area should have been identified and recovered. If not, investigation of the cause of this failure is necessary.
- For MPPEH, the contractor's QA/QC program ensures:
  - MPPEH is 100% inspected and 100% reinspected.
  - Documentation of the inspections is developed and maintained.
  - Material documented as safe (MDAS) is segregated and secured until release to a recycler.

Inconsistencies between reported findings and anomaly characteristics should be resolved (feedback process, section 3.4.1.4). In general, the project geophysicists will define groups of criteria, based on various anomaly characteristics, to define what will be deemed acceptable reported dig results that explain the anomaly without need of additional validation or verification. Anomalies having dig results that do not match predetermined physical and burial characteristics necessitate further validation and verification by the geophysicist and might necessitate revisiting the anomaly location to confirm nothing of interest remains or to identify additional excavation needs.

3.6 Verification Sampling

Verification sampling is a statistical sampling method and tool sometimes used for post-remediation verification to demonstrate MR project objectives have been achieved. Verification sampling is conducted on completed portions of the production area after the UXO contractor reports satisfactory completion of work in that area. See box (next page) for a historical perspective on the origins of verification sampling.

Historically, verification sampling consisted of an independent contractor performing a duplicate geophysical survey on a portion of the completed project. Finding a "nonconforming condition" (e.g., remaining UXO/DMM or other metallic object that should have been detected and removed) should be cause to question the adequacy of the work in the area being inspected and possibly cause for requiring rework of the area.

Today, recent technical advances in geophysics and improvements in process QC make traditional verification sampling less important (see box). The current MR QC philosophy[1] is that implementing appropriate process QC, including blind seeding of the production area, is more valuable for determining whether or not the project objectives have been achieved.

[1] This assessment of current QC philosophy is based on a survey of MEC experts representing state and federal regulators, contractors, and DOD MR technical and management personnel who are members of the UXO Team.

Verification Sampling: A Historical Perspective

Civilian contractors began performing MEC work for DOD in the 1980s. At that time, "mag and dig" surveying using handheld magnetometers was the only technology available to perform this work. DGM equipment and processes were not available, leaving limited options for performing process QC. There are inherent difficulties in performing process QC on "mag and dig" projects—including the fact that every geophysical system (consisting of the geophysical instrument and the human operator) is different and has different detection capabilities. For this reason, project managers needed a way to convince stakeholders and regulators that a completed project met some type of acceptable standard for quality, and verification sampling on MEC projects was developed.

Originally, it was decided that an adequate amount of verification sampling was 10% of the survey area. This amount of verification sampling is frequently still used today. However, there is little or no statistical justification for the selection of this round number. When the 10% standard began to be questioned, it was proposed that the requirements of MIL-STD-1916 (DOD 1996) be used. This military standard is used throughout industry to sample completed manufactured products for quality acceptance and includes procedures for determining random sample sizes based on the size of the "lot," the level of confidence required in the adequacy of the finished product, and the past performance of the contractor.

However, applying MIL-STD-1916 sampling protocols to MR projects is difficult and somewhat controversial. Because of this issue and the technological improvements associated with DGM geophysics, MR project QC has evolved toward using a rigorous process QC program to ensure that the finished product meets the project goals and detailed DQOs. This emphasis on process QC is also consistent with MIL-STD-1916, which emphasizes the importance of a rigorous process QC program.

The success of projects using rigorous process QC to develop stakeholder confidence has increased the importance of process QC and decreased the importance of verification sampling. However, verification sampling is still being used today and is appropriate on certain types of projects. See section 4.5 for an example.

However, verification sampling is still used today and may be important on some specific types of projects (see section 4.6), and may also be valuable for increasing the project stakeholders' confidence in the quality of the overall project.

The decision about whether or not to include verification sampling as a final acceptance criterion should be evaluated and made during the project planning process. In addition, the decision and the specific verification sampling requirements that need to be met should be documented in the MR project work plan.

3.6.1 Verification Sampling Tasks

Verification sampling involves performing independent geophysical surveys and investigation of anomalies on the completed project site. Usually the same type of geophysical sensor and geophysical processes that were used for the production survey are used for verification sampling.

The verification sampling is often performed by an independent "QC geophysics team" or sometimes an independent contractor. This approach prevents a possible conflict of interest between the managers of the production surveys (tasked with completing the project on time and budget) and the QC managers (tasked with ensuring that project quality meets the established requirements).

The following are typical ways to perform this process:

- The method of verification is included in the work plan along with the requirements and the actions to be taken in the event of a nonconforming condition.
- Verification sampling geophysical surveys are performed as planned by an independent team or contractor.

- Identified anomalies which may represent nonconforming conditions (UXO/DMM or other objects that should have been identified and removed during the production survey) are excavated.
- If the results of the verification sampling are negative (no nonconforming conditions are discovered), the "lot" comprising the verification sample is accepted as meeting the project objectives.
- If the results of the verification sampling are positive (nonconforming conditions are discovered) appropriate corrective action is taken. Possible corrective actions may include performing a root cause analysis and rework of the affected "lot."

3.6.2 Key Factors to Consider for Verification Sampling

- Will verification sampling be one of the QC checks to determine the acceptance of completed areas of the MR project?
- What statistical confidence is required in the results?
- How will the individual areas subjected to verification sampling (lots) be selected?
- How will the percentage subjected to verification sampling of each lot be determined?
- What method (e.g., Visual Sample Plan, see box) will be used to determine the sampling design?
- What equipment and procedures will be used to conduct the inspection?
- What constitutes a nonconforming condition?
- How will nonconforming conditions be addressed?
- Is the process QC capable of adequately assessing the geophysical processes being used for the production MR survey?
- How much verification sampling is needed to increase confidence in the completed project to an acceptable level?

Visual Sample Plan

Visual Sample Plan (VSP) 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. VSP is designed primarily for project managers and users who are not statistical experts, although those individuals with statistical expertise also will find the software very useful. Reports produced by VSP can be pasted directly into a QAPP or a sampling and analysis plan. VSP can be used to implement EPA's systematic planning process for a variety of problems.

VSP also contains several statistical tools for characterizing sites potentially impacted by UXO/DMM. These statistical tools help identify and delineate potential target areas at a site using limited amounts of geophysical transect data. Additional tools are available to determine transect spacing, delineate boundaries, and map geophysical anomaly density. VSP may also be used to develop a verification sampling plan that can be used to demonstrate, at a specified confidence level, the adequacy of an MR Project.

3.6.3 Controls: How and Where to Monitor

For DGM surveys, verification sampling is usually accomplished by performing an independent geophysical survey on an agreed-upon portion of a completed area or "inspection lot." For example, if the "lot" is composed of geophysical survey lanes that may be relocated, then a random number generator can select lanes to be resurveyed. Working from an approved QC plan, the QC geophysics team will locate the selected lanes, collect geophysical data, process the data and select anomalies for investigation. The selected anomalies are then excavated to determine whether they constitute "nonconforming conditions"—objects that should have been detected and removed during the original production area survey. If so, then appropriate corrective actions, such as performing a root cause analysis or performing rework of the "lot," will be implemented.

The procedure outlined above is not possible on some projects (e.g., surface removal), where search lanes are not delineated in permanent or reproducible fashion. In these cases, verification can be performed by walking over a percentage of the "inspection lot" while checking for UXO/DMM.

4. CASE STUDIES AND LESSONS LEARNED

The following five case studies illustrate application of the process approach to managing the quality of an MR project. The first three examples discuss several characteristics specific to MR projects that are mentioned earlier in the document (e.g., accurately defining requirements) and further explore how a process-driven approach—both adequate and inadequate—can impact the outcome. The final two examples are detailed explorations of QA/QC measures at two MR sites presented as case studies: Adak Naval Complex in Alaska and the Diamond Springs Road and Guthrie Road areas near Helena Valley, Montana. The reader is encouraged to review these case studies to gain a better understanding of how good QA/QC practices can and have directly affected the success or failure of MR.

4.1 Performance Requirements: Where Is the Surface of the Earth?

A successful MR project will have well-defined project goals, processes, and requirements and a program to monitor (QA/QC) the "quality" of each process. UXO/DMM removal requirements or requirements such as clearance depths must be based on a certain frame of reference clearly understood by everyone involved with the MR Project. Typically, that frame of reference is the "surface" of the earth (i.e., remove all UXO/DMM from the ground surface or clear UXO/DMM from the ground surface to 2 feet below ground surface). If the project team cannot agree on exactly where the surface of the earth is or, worse, each member assumes a common point of reference when in fact each has a different definition of where the surface of the earth is, reaching an agreement on when the project is complete will likely be contentious. In this particular example, the success of the MR project hinged upon the success of the surface removal process. However, before establishing the requirements for surface removal, defining exactly what was meant by the "surface" became a key decision for the project team. Precisely defining the surface of the earth was vital to the success of this MR project, and as this example demonstrates, became a much more difficult task than one might expect.

The Aleutian Islands are a chain of more than 300 small volcanic islands forming an arc in the Northern Pacific Ocean extending about 1200 miles (1900 km) westward from the Alaska Peninsula toward the Kamchatka Peninsula, Russia. In 1942, during World War II, the Japanese Army forcibly occupied two of the Aleutian Islands. The U.S. military established an air base in Adak, Alaska and forcibly removed the Japanese from the islands in 1943. As a result of this activity, some areas of the islands contain UXO/DMM.

The "surface" is typically defined as the top layer of mineral soil. However, the Aleutian Islands are covered with tundra, characterized by spongy, mat-like, low-growing dense vegetation that can be up to 3 feet thick. Because of the tundra, the defining the surface of the earth assumed a new level of unexpected complexity. The project team for the MR project on Adak Island raised this issue while planning the surface removal phase of the MR project. As a result of this discussion, the project team developed the following three answers to the question, “Where is the surface of the earth?”:

1. The surface is the top of the tundra. It is where the disturbance will take place when someone walks on the tundra and is comparable to the top layer of mineral soil on a site without tundra.
2. The surface is the top of a dense layer of vegetation within the tundra. The surface is a certain density of the tundra vegetation that will not compress or move when someone walks on it. This would be comparable to the top layer of mineral soil on a site without tundra vegetation.
3. The surface is the top layer of mineral soil under the tundra vegetation. This definition of surface is comparable to the top layer of soil on any other site with vegetation other than tundra.

Following vigorous debate, the project team decided that the surface of the earth—for this MR project—was the top layer of soil under the tundra. In the end, definition 1 was rejected because the team decided it was not protective of persons walking on the tundra. Persons walking on the surface or top of the tundra might create enough pressure to compress the tundra and disturb UXO or DMM that lay beneath the tundra. The project team rejected definition 2 because it required a nebulous standard of tundra density that would be difficult to quantify and measure in the field. Years after this planning meeting, members of this project team still laugh about how they participated in a vigorous debate concerning the location of the surface of the earth. Without this discussion, however, it would have been impossible to develop and agree to a requirement for surface removal on Adak. The importance of the project team making this determination before implementing the MR should not be underestimated. Without clearly defining “surface of the earth,” establishing requirements for what is “clean” would have been impossible.

4.2 Lazy Assumptions Lead to Inadequate Performance Requirements

Conformance to requirements (quality) may not be adequate if the requirements are poorly developed. If requirements are too lax, not appropriate to the task, or assumed, the quality of the product may be jeopardized. In this example, an MR project team contracted a surface removal team to clear all UXO/DMM from the surface of a survey area. The surface of the survey area had to be completely clear of all UXO/DMM before the MR project team could begin digital geophysical investigation of the area.

The MR project team identified surface removal as a key process of the MR project. It required detecting and removing surface UXO/DMM, including that hidden under forest vegetation debris. Because UXO/DMM may be visibly obscured by vegetation, the surface removal team decided to use handheld magnetometers to aid in detecting hidden UXO/DMM.

The performance requirement approved by the MR project team for the surface removal process was simple: “Find and remove all surface UXO and DMM from the survey/production area.” The QA/QC for this particular requirement necessitated the QA/QC team inspecting all areas "cleared" by the surface removal team. Under this performance requirement, finding *any* UXO or DMM on the surface anywhere in a "cleared" area, hidden or otherwise, would constitute a nonconformance, or failure. A nonconformance would trigger a root cause analysis, possibly a corrective action, and/or a resurvey of the entire area. The performance requirement seemed appropriate. It reflected the goal of the process, which was to remove all surface UXO/DMM from the survey area.

After the surface removal team completed a sweep of a portion of the survey area, the QA/QC team conducted a QC check and discovered a large piece of scrap metal on the surface obscured by vegetation that clearly had not been investigated by the surface removal team. The QA/QC team reported the piece of metal as a nonconformance and recommended halting the surface removal process, conducting a root cause analysis, and resurveying the area. The QA/QC team suggested that the cause of the nonconformance was the surface removal team's failure to survey 100% of the production area but had no evidence that this was the cause of the nonconformance. The surface removal team claimed it had in fact surveyed the entire area, and this statement was reinforced by the surface removal team leader. In fact, the leader claimed the team had met the process requirement of detecting and removing all UXO/DMM from the survey area. He made this claim because the large piece of metal discovered by the QA team was not UXO or DMM, but merely scrap. Therefore the discovery of "scrap" was not a nonconformance, and any resurvey of the area would require a modification to their contract.

Based on the recommendation of the QA/QC team, The project team decided to halt the MR project and examine the surface removal process. Upon review, the project team determined the following:

- Some performance requirements were assumed or not defined.
- The original performance requirement for the process did not account for limitations of the equipment. The equipment limitation was that handheld magnetometers are not able to distinguish UXO and DMM from other similarly sized pieces of ferrous metal on the surface.
- The monitoring system (QA/QC) for the process was inadequate to provide sufficient evidence that the removal team met process requirements. The QA/QC team conducted a QC check on only the finished product, resulting in untested or unmonitored process tasks. The project team was thus put into the position of assuming that the completed tasks met all process requirements. The untested or assumed requirements were that handheld detectors always function properly and that the surface removal team would cover 100% of the site.

The original process requirement did not take into account that handheld magnetometers cannot discriminate between the objects that they detect. For example, if the instrument detects a ferrous metal object, the object may be UXO, DMM, or scrap. Until the object is visually inspected, the object must be regarded as UXO or DMM. Consequently, any ferrous metal object that is overlooked, not detected, or not inspected is a nonconformance and should constitute a failure.

Moreover, the QC activities for the process evaluated only the "finished product"; as a result, the QC inspection could check only for the presence of UXO or DMM in a "cleared" area. There was no way to confirm that the detectors were always functioning properly or whether the survey team had indeed covered 100% of the survey area. Therefore, there were no monitoring data to support a proper root cause analysis of the process once a problem was discovered.

Faced with these uncertainties, the project team had no choice but to revise the requirements and repeat the surface removal process. The revised requirements were in part as follows:

1. Process: Surface removal of UXO and DMM
2. Purpose: To remove all UXO and DMM from the surface of the survey area for follow-on DGM
3. Requirements:
   a. Survey 100% of the survey area.
      - Establish survey lanes in the survey area using temporarily fixed reference points.
      - Assign one person per survey lane.
      - Ensure that spacing between survey team members does not exceed 6 feet.
      - Use survey-grade GPS to track and monitor survey team position.
      - Conduct GPS functionality tests daily.

   b. Examine all pieces of surface metal that are detected (visually or with magnetometer) in the survey area including any metal objects that may be hidden under forest vegetation (leaves, pine needles, etc.). Determine whether detected items are UXO, DMM, or scrap. Mark scrap that resembles (or is similar in size to) UXO or DMM with orange spray paint.
   c. Conduct and record magnetometer functionality tests daily.
   d. Remove all items identified as UXO and DMM from the survey area.
4. Monitoring activities (QC checks) for this process include the following:
   a. Ensure that survey lanes are properly marked.
   b. Verify spacing between individuals.
   c. Ensure that the survey team is producing a GPS track log of the survey.
   d. Record results of GPS functionality tests.
   e. Ensure that the survey team is conducting magnetometer functionality tests.
   f. Conduct blind seeding of scrap and surrogate munitions in the survey area.
   g. Conduct final QC inspection of "cleared" area.
      - No UXO/DMM or seeded items shall remain in the survey area.
      - All UXO/DMM-like scrap remaining in the production area must be marked with orange paint.

Failure to meet the QA/QC checks for these requirements would constitute a nonconformance and may require a root cause analysis, a corrective action, and a resurvey of the area affected by the nonconformance.

The discovery of undetected UXO-like scrap by the QA/QC team produced an uncomfortable level of anxiety for the project team. Because the project team failed to consider the limitations of the detectors and how they are used and assumed certain levels of quality that could not be validated, the quality of the initial surface removal was suspect. In addition, the project team was unable to require the surface removal team to resurvey the area because, based on the original performance requirement, the surface removal team was right—QC did not find any UXO or DMM in the survey area. Fortunately, an experienced QA team was on hand to identify the problem. The project team was able to refine process requirements and develop a more robust QC monitoring system to ensure the surface removal process would produce, with confidence, the desired product.

4.3 Failing to Identify the Needs of the Customer

Product requirements that are not consistent with what the customer wants or needs may result in a product that "conforms to requirements" but is not very useful to the customer who needs a certain product or service. On one MR project, for example, the project team did not consult with the geophysicist to find out how much vegetation had to be removed from the production area. This caused a major difficulty for project team when the geophysicist arrived on site to conduct the DGM survey.

After the vegetation clearance team completed the task of removing vegetation, the geophysical survey team mobilized to the site to begin operations. However, upon arriving at the site for the first time, the geophysicist quickly realized that his team could not perform the DGM survey because the remaining tree stumps were too tall and too many obstructions remained on the site to allow the deployment of the wheeled EM 61 sensor.

The project team evaluated the situation, including the extra cost of remobilizing the vegetation clearance team. Based on the time involved and additional cost of remobilization, the project team decided to change the geophysics survey from DGM to "mag and dig."

In this case, failure to understand the needs of the customer on a relatively straightforward field operation caused the technical approach of the follow-on process to change. Modifying the technical approach may compromise or adversely affect the integrity of the MR project. Clearly recognizing and understanding the needs of the customer is vital to identifying product requirements.

4.4 Verification Sampling

Analysis of a "mag and dig" project completed in 2007 demonstrates that verification sampling still may be useful in MR projects. This project was a surface UXO/DMM removal using handheld geophysical sensors to detect metal objects on or above the mineral soil layer but under forest debris and vegetative matter, including thick pine needle deposits.

This project employed appropriate process control, including sensor function checks performed twice daily and QA/QC personnel observing the implementation of the surface surveys. However, since each person and sensor represents an individual geophysical system with no recorded data to inspect, this type of survey process is difficult to control.

As a result, the project managers decided to perform verification sampling on at least 10% of each "lot." After a few weeks of operations, the QA/QC verification team began to find large ordnance fragments on the surface of the mineral soil layer but under the forest vegetation. Since these large fragments should have been detected and investigated in accordance with the requirements of the statement of work, it was determined that they constituted nonconforming conditions.

A root cause analysis was performed, and it was determined that some of the contractor's personnel had become complacent and were not investigating all of the detected anomalies beneath or obscured by forest vegetation debris. An emergency QA/QC meeting was held, including all of the contractors and DOD managers involved. It was determined that the completed work did not meet the overall project objectives and requirements even though the process controls were implemented as planned. A recovery plan was developed and a significant amount of rework was performed. Follow-on verification sampling confirmed satisfactory results.

This case study demonstrates that, even though verification sampling is becoming less important to DGM project, it still has a place as a valuable QA/QC tool, especially on "mag and dig" projects.

4.5 Development of a Munitions Response Quality Assurance Project Plan for the Former Naval Air Facility Adak, Alaska, Operable Unit B-1

4.5.1 Site Background

Adak Island is located in Alaska's Aleutian Islands. Military use of Adak Island began with the Army in World War II when it was used as a staging and combat training area for troops preparing to retake two Aleutian Islands that were occupied by the Japanese. Following WWII, military operations on Adak Island were dramatically reduced. The U.S. Air Force (succeeding the U.S. Army Air Corps) had a post-WWII presence on Adak until 1950. In 1953, the Navy took over facilities on the island, which served as the base of operations for the North Pacific submarine monitoring network and served other purposes throughout the Cold War.

Cleanup of Adak under CERCLA (Superfund) regulations began once the island was added to the National Priority List (NPL) in 1994. Operable Unit (OU) B is the designation for the MEC sites, and which are divided into two subunits. OUB-1 contains numerous WWII munitions sites located on the northern half of the island. Three of these sites (MM-10F, MM-10G, and MM-10H) are the subject of this case study and are located in areas designated for transfer to U.S. Fish and Wildlife Service (USFWS) once remediation is complete.

4.5.2 MR QAPP for Operable Unit B-1

According to the UFP-QAPP Manual (EPA/DOD/DOE 2005a, b, c):

> A QAPP is a formal document describing in comprehensive detail the necessary quality assurance (QA), quality control (QC), and other technical activities that must be implemented to ensure that the results of the work performed will satisfy the stated performance criteria. A QAPP presents the steps that should be taken to ensure that environmental data collected are of the correct type and quality required for a specific decision or use. It presents an organized and systematic description of the ways in which QA and QC should be applied to the collection and use of environmental data. A QAPP integrates technical and quality control aspects of a project throughout its life cycle, including planning, implementation, assessment, and corrective actions.

The QAPP manual was developed by the Intergovernmental Data Quality Task Force, which included representatives from EPA, DOD, and DOE. The QAPP guidance developed by the Task Force uses a series of worksheets, available in the *QAPP Workbook* (EPA/DOD/DOE 2005c) to guide the development of the comprehensive QAPP. The 37 worksheets in the *QAPP Workbook* serve as a format for project planning from basic project administrative information, through the establishment of project objectives and detailed DQOs (requirements), to highly detailed quality inspections and analysis of data usability.

Unfortunately for the MR industry, the QAPP was designed for projects focused on collecting environmental chemical data and not data specific to quality requirements for MR projects (i.e., geophysical surveys, intrusive investigations, etc.). Several MR project managers have looked at using the QAPP format for planning MR projects, but the complex task of converting the environmentally focused worksheets to be suitable for geophysical data collection and the other processes associated with MR projects was daunting. Because of this, portions of the QAPP have been used on MR projects, but until recently full development of an MR UFP-QAPP had not been successfully undertaken.

The Adak project presented a unique opportunity because the Navy, state, and federal regulators could not agree on acceptable requirements and the QC to ensure that adequate MEC investigation and removal were being performed in remote areas of Adak. To meet that challenge, the project team decided that a QC plan developed in accordance with the UFP-QAPP would be acceptable.

Following this decision, the Navy tasked its contractor to develop an MR work plan that included an MR UFP-QAPP. The existing work plan was reduced to contain only basic background information and to serve as the cover document for the MR QAPP and the supporting SOPs. The project team decided that all of the quality-related technical information on the project would be contained in the MR QAPP and the detailed "how to" instructions to the contractor's field personnel would be contained in the SOPs. One of the main benefits of using this format was the elimination of duplicate technical information. Each document (the brief technical and management plan, the MR QAPP, and the SOPs) had a specific purpose that was not duplicated by other documents. This approach resulted in an immediate streamlining of the overall work plan with improved ease of use and less disagreement among the various documents.

Because of the very tight time schedule for the upcoming Aleutian field season, the Navy agreed to develop this first MR QAPP jointly with the regulators. In a two-day meeting, the existing technical and management plan was converted into a brief work plan and a MR QAPP with detailed SOPs. The resulting MR QAPP–based project work plan is available for review at www.ert2.org/T2MRPortal/pages/mrqa.html. Persons interested in the details of how the UFP-QAPP was modified into the MR QAPP may contact either the U.S. Navy or Alaska Department of Environmental Conservation team representative (contact information is in Appendix B).

4.5.3 Developing the MR QAPP

The following are examples of major modifications that were required to apply the UFP-QAPP to MR projects:

- The following worksheets were found to be not applicable to MR projects: 15, 19, 20, 23, 24, 25, 26, 27, 28, and 30. (The worksheets were not deleted; instead, they were left uncompleted, with "Not Applicable" written as a watermark on the page.)
- Worksheet 10 was used to develop and present DQOs.
- Tasks (in this document called definable features of work [DFWs]) were developed on Worksheet 14. These DFWs make up the basic tasks of the project and are consistently used throughout the remainder of the MR QAPP.
- Worksheet 17 is a narrative description of the technical approach to achieving the project goals.
- The SOPs are described on Worksheet 21, with an SOP to describe how to perform each DFW.
- Worksheets 34, 35, and 36 are the critical "bottom line" of the QC program. These tables perform the following functions:
  - Worksheet 34 contains all of the QC performed prior to beginning production work, including the GPO and the preparatory and initial QC inspections for each DFW.
  - Worksheet 35 contains all of the follow-on inspections for each DFW, including the required frequency of the inspections, who performs the inspection, and the pass/fail criteria. Worksheet 35 is similar to the example QC checks shown in Table 2-1 of this document. *It is important to note that for the OUB1 MR UFP-QAPP, the contractor submitted very detailed QC inspection forms with each SOP. The project team decided that, instead of converting all of these inspection forms to the Worksheet 35 format, these would serve as the basis of the QC program and would be referenced in Worksheet 35. The project team was willing to accept either format, and leaving the QC inspection forms in the SOPs required the least effort for the contractor.*
  - Worksheet 36 contains a description of the area of concern certification process. The procedures on this worksheet, if appropriately implemented, will be sufficient to achieve stakeholder and regulator concurrence that the project has been implemented in accordance with the work plan.

The importance of Worksheets 34, 35, and 36 is that they provide detailed descriptions of the QC inspection program from start to finish. With this guidance, the field QC personnel should clearly understand the QC functions they are assigned to implement.

In summary, the Adak MR QAPP is the first full implementation of the UFP-QAPP guidance to an MR project. Implementing the UFP-QAPP on the Adak MR project gave the project team work plans that were both complete and concise and a considerable improvement over other work plan formats. One significant benefit of the UFP-QAPP is that it encourages the project team to work together in developing project requirements in a logical and sequential manner.

MR project managers are encouraged to use the Adak MR QAPP as a starting point or template for development of their own MR QAPP. Through the Adak project team's unique adaptation of the UFP-QAPP, the MR QAPP format may become the standard for MR projects.

4.6 Quality Assurance and Quality Control in UXO Remediation—A Case Study from Montana

This case study is adapted from *Quality Assurance and Quality Control in UXO Remediation—A Case Study from Montana* with permission from its authors. Since 1997, the Montana National Guard (the Guard) has implemented systematic UXO survey and removal actions on 420 acres of residential property in two separate impact areas (the Diamond Springs Road and Guthrie Road areas) in the north Helena Valley, Montana. The survey work resulted in the removal of a total of 136 mortar and artillery rounds (of which 28 were UXO or ordnance and explosive waste).

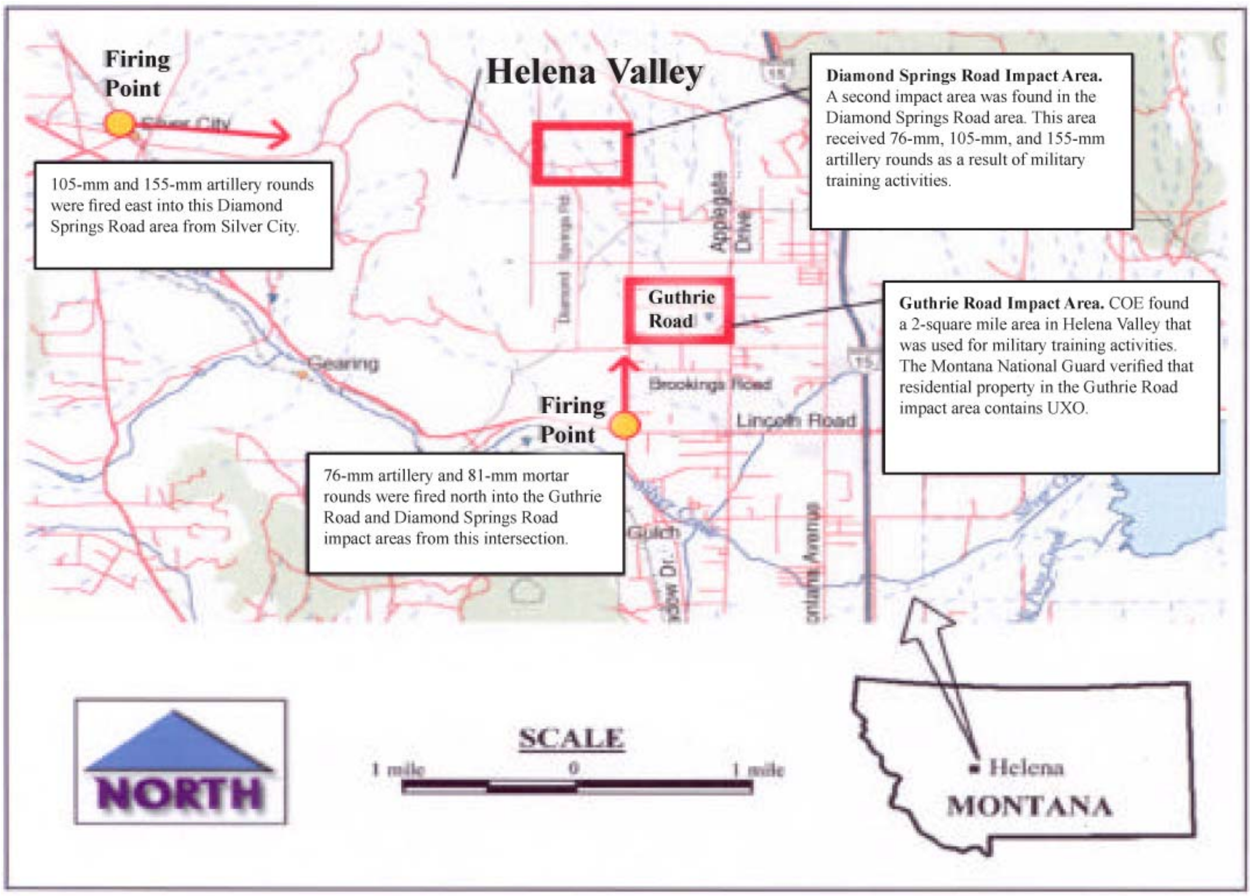

Figure 4-1. Map of UXO survey of contaminated sites in Helena, Montana.

QA methods in UXO clearance operations are fundamental to obtaining a reliable estimate of residual risk and hence "success." The theme of this case study is the role QA and QC played in UXO remediation efforts in the Helena Valley. As will be shown, the Guard went to considerable effort to incorporate QC and QA methods early on in this project due to confrontation with much uncertainty. These measures allowed the Guard to match the site with the best subsurface UXO detection technology, assess the performance of this technology, and quantify performance results.

When the project began, the Guard was uncertain about the site-specific capability of the subsurface UXO detection technology and about the types and level of contamination on the site.

Results from Phase II and III of the Advanced Technology Demonstration program at Jefferson Proving Ground (JPG) showed that there is often a considerable disparity between expected and actual detection efficiency. The Guard recognized early the need for a way to evaluate how well the methods were working. In addition, the Guard was uncertain as to how to best collect, manage, and present the data obtained during survey work, feeling strongly that the public should have unrestricted access to the results and that results should incorporate a simple means for the layperson to evaluate the effectiveness of efforts. The Guard felt that such openness would advance public confidence, even if detection fell short of 100%. In many ways, it was uncertainty that drove the Guard to find better ways to collect, interpret, and manage data.

This case study discusses how QA/QC measures were incorporated early on and at each step throughout the project, and more specifically how QA/QC were applied to project planning activities, geographic information system (GIS) mapping, surface sweep, emplacement, geophysical survey, and validation activities.

4.6.1 Project Planning Activities

Initial project planning activities consisted of an extensive archival research that incorporated interviews of former guardsmen, an on-site surface assessment by explosive ordnance disposal (EOD) technicians, site selection and delineation, and geophysical characterization.

The size of the area selected for remediation at each site was constrained by limited funding and personnel. Therefore, the Guard had to prioritize the areas to include in the initial remediation effort. Areas where exposure was highest due to the presence of homes and residential activity were selected as top clearance priority. At the Diamond Springs site, a 220-acre area of private property was delineated where homes had been built and from which UXO had been recovered. This area was several hundred meters south of where the Guard determined the actual center of the artillery impact area to be located. The Guard could not have adequately supported a remediation of a significantly larger scale.

Ballistic modeling was conducted to estimate the depth at which UXO could be expected to be found. Ballistic modeling, along with subsequent validation data, allowed deviation from the clearance depth default standard of 10 feet (chapter 12, DOD STD 6055.9) and to narrow the search depth. Records indicated that 105, 155, and 76 mm rounds had been fired into the Diamond Springs Road area. Ballistic modeling results predicted that a 155 mm round could penetrate the hard shales on the site to a depth of 8 feet. Data gathering for Guthrie Road indicated that 76 and 81 mm rounds were present in that area, and ballistic modeling indicated that the M43 series 81 mm mortar penetration would not exceed 3 feet at this site.

4.6.2 GIS Mapping/Grid Survey

A system of 100 × 100 m grids across the Diamond Springs and Guthrie Road areas was established. Positional reference at Diamond Springs required the establishment of a grid system. Navigation of the geophysical survey equipment was ground-referenced to the grid system at Diamond Springs. The presence of a grid system facilitated navigation across the site during all subsequent phases. Each grid stake was marked with the NAD 83 easting and northing coordinates, allowing quick positional reference and the ability to navigate to within 1 m of an anomaly with nothing more sophisticated than a set of survey tapes. This grid system allowed the total station electronic distance measuring (EDM) survey team to set up at many locations to quickly and more accurately survey anomaly positions. At Guthrie Road, the grid system allowed the Guard to quickly check the initial DGPS positioning results from the geophysical survey.

The grid system facilitated differential rectification of preexisting aerial photographs. These differentially rectified photographs served as base maps using Arc View GIS for both Diamond Springs and Guthrie Road. This technology proved extremely useful at Guthrie Road. The GIS technology allowed a variety of maps to be produced rapidly, each tailored to depict a specific QA question. For example, all "high confidence" anomalies that met certain QA criteria could be extracted from a spreadsheet. Using GIS, extracted anomalies could be quickly plotted onto the base aerial photograph, and a GIS map could be printed for use in the field.

4.6.3 Surface Sweep

The Diamond Springs surface sweep was contracted to a commercial firm. The detection rate of surface UXO was under 50%. There are several reasons for this low detection rate. The Guard was unfamiliar with the detection capabilities of surface sweeps in general and in particular with what to expect from a commercial UXO contractor. Consequently, there were no provisions in the contract specifying a performance standard. Limited funding precluded such language. There were no QA measures in place prior to the surface sweep. The Guard had too little experience with detector-aided surface sweeps to feel confident enough to insist that UXO technicians "slow down" or rely less on Schonstedt flux-gate magnetometers and more on visual acquisition of MEC (UXO/DMM). Better results may have been seen if inert ordnance had been emplaced on the surface as a QA measure.

The high cost and low detection of surface MEC at Diamond Springs led the Guard to seek the support of Montana Air National Guard 120th Fighter Wing EOD team. This team had performed well during the validation work of Diamond Springs and volunteered to perform the surface sweep at Guthrie Road. Several intact mortar rounds were recovered during the surface sweep; however, numerous other intact rounds and large pieces of surface shrapnel were missed. No QA measures were used during the surface sweep, as the Guard believed that having its own EOD team would solve the problems encountered at Diamond Springs. Again, had the EOD team been challenged with QA measures, the Guard could have demonstrated that ordnance and scrap metal were being missed too often.

What are the consequences of a poor surface sweep, and how do they relate to QA? The first consequence is the failure to substantially reduce the exposure to surface MEC so that the geophysical and land survey teams are exposed to more danger. The second consequence is that large pieces of shrapnel and ordnance-related scrap are missed along with UXO. As ordnance-related metallic debris and large segments of rounds—such as were often encountered in the form of 76 and 81 mm white phosphorus rounds—are very difficult to discriminate from the geophysical signal produced by actual UXO. The surface presence of such items at the time of the geophysical survey results in an increase in the number of geophysical anomalies that cannot be discriminated from MEC. False positive rates profoundly influence overall clearance costs because they require multiple subsequent actions, each costing time and money.

4.6.4 Emplacement for Quality Assurance

For the Diamond Springs Road emplacement effort, the Guard determined the types of ordnance that could be present based on three sources: archival search activities, preliminary site characterization, and surface sweep results. Inert ordnance that was of the same age, condition, and type as recovered from the site was selected. Whenever possible, the Guard used inert ordnance that was recovered from the site. Inert ordnance from the site ensured a close signal match with the magnetic properties of actual UXO. This method reduced bias in estimating detection efficiency.

Inert rounds were emplaced at depths and orientations representative of actual penetration depths as determined from ballistic modeling (CONWEP). Many of the rounds were emplaced in the least favorable orientation for detection (azimuth was horizontal and long axis of round oriented along perpendicular to the earth's magnetic field). The rounds were concealed, and ground disturbance was concealed when possible. When a backhoe was needed to bury rounds at depth, ground disturbance could not be concealed. Instead, two additional "empty" digs were made.

Rounds were emplaced in specific orientations and depths. This information was recorded on preprinted emplacement worksheets, which could then be shared with geophysical contractors for comparison of results once the anomaly was declared. The same process for selection of representative inert ordnance was used for the Guthrie Road emplacement. The relative position of emplaced ordnance was surveyed to allow estimates of positional accuracy. Note that it was the knowledge of the position of emplaced rounds that led to identification of systematic position error by the geophysical survey contractor. This knowledge allowed the contractor to fix this error in the field in less than 24 hours. Had this error not been identified, the entire project could have been jeopardized.

4.6.5 Geophysical Technology Selection

JPG II and III demonstrated that site conditions can have significant influence on performance. Preliminary site investigation of the geology of Diamond Springs indicated that the site should have little noise from mineralized soils as the site was primarily of Pleistocene shale. Ballistic modeling along with data on the types of UXO to be expected led to the conclusion that total field (cesium-vapor) magnetometers would be the best choice because rounds would be looked for at depths as great as 8 feet in a geologically quiet substrate.

In the selection of a geophysical contractor, the Guard looked to firms with a demonstrated ability to find UXO at high detection efficiency, using JPG II demonstration results to select potential bidders and looking at each firm's JPG record or equivalent experience, cost, and overall credentials. The contractor selected used a man-portable, dual-sensor cesium-vapor magnetometer (Figure 4-2). Relative position information was tracked using a cotton thread odometer.

Figure 4-2. Man-portable, dual-sensor cesium-vapor magnetometer.

In contrast to the Diamond Springs area, the Guthrie Road area was littered with shrapnel. The experience at Diamond Springs demonstrated that large shrapnel and pin flags are hard to discriminate from UXO. High levels of shrapnel create a serious problem with "noise."

Geophysical tests were conducted with a variety of instruments that confirmed the presence of large amounts of noise from shrapnel. In-field equipment tests by the contractor demonstrated that its cart system could filter shrapnel and still detect UXO. The Guard concluded that the best way to handle the problem was through a multiple-sensor towed array with sensors close to the ground and highly accurate positioning capability (Figure 4-3).

Figure 4-3. Multiple-sensor, towed-array system.

4.6.6 Physical Location of Geophysical Anomalies

After completing geophysical surveys of the Diamond Springs and Guthrie Road areas, the contractor provided the Guard with the locations of all detected geophysical anomalies within the two areas, prioritizing the anomalies as high, medium, or low confidence. Also provided was a list of "junk" anomalies, those in which a metallic item is present but in which the item does not model like UXO. Each geophysical anomaly that was validated was first located in the field by conducting an EDM survey. The anomaly location was marked in the field with both a survey flag and an aluminum tag attached to a 6-inch steel nail. Each aluminum tag was inscribed with the anomaly number and became known as the "validation tag."

4.6.7 Anomaly Validation

The results of each anomaly validation were recorded on a validation sheet completed at the time of the validation, consisting of a series of data blocks, each with specific questions that relate to the size, shape, orientation, depth, and position of the item found. The Guard required that detailed information be collected for ordnance and nonordnance alike. A photograph of all intact ordnance was taken. The method used required that the aluminum tag with the anomaly number be handled in one of two ways: (1) attached to the validation sheet if the anomaly was nonordnance or (2) attached directly to the ordnance if the item was an intact round. This system ensured a means of accounting for the status of each reported anomaly.

It was recognized that some irreducible uncertainty about validation results would exist, stemming from the fact that each geophysical anomaly identified in the initial survey must be relocated during validation. Because detection equipment used by EOD during validation (Vallon 1620B and Ferex®) does not have the same signal discrimination capability as a cesium-vapor magnetometer, it is possible that the anomaly's actual source will not be located. This possibility increases as the density of shrapnel and metallic debris increases. It was difficult to discriminate near-surface items from deeper anomalies. If positional accuracy is suspect, validation can be tedious and time-consuming. Uncertainty is lowest when positional accuracy is high (<50 cm), discrimination capability is known to be high, and the match between the item found and the reported anomaly is good.

The detailed information on the validation sheet could be used to evaluate the quality of the match between the object found by EOD and the anomaly identified by the geophysical team. When there was asymmetry in this match (i.e., small object found, but large dipole reported), additional QA measures were taken.

4.6.8 Additional QA Measures

During the Guthrie Road validation, Air Guard EOD technicians defined about 100 points as "nothing found" points, which could mean one of two things: (l) the EOD technicians detected a magnetic deviation but could not find an obvious source of the anomaly, or (2) the EOD technicians could not detect an anomaly with their equipment because the anomaly was moved, their equipment was used improperly, or the anomaly was outside of the range of the equipment. In about 9% of the points, no geophysical anomaly could be detected. These sites had to be checked for positional accuracy, and if positional accuracy was found to be correct, then the original source of the anomaly remained unknown. The Guard did not want any unresolved anomalies in a residential area and thus sought to resolve the anomalies by using a similar technology to attempt to replicate the result. Another geophysical surveying contractor was brought to the site to look at approximately 75 of these locations using a quad-sensor, cesium-vapor magnetometer. After reviewing the resulting data, a UXO technician from a separate contractor reinvestigated all 100 "nothing found" points. The points were revalidated with a fluxgate magnetometer. No additional discoveries were made; however, fragmentation and metallic debris were found at some of these sites.

This QA check led to the discovery of 15 anomaly points that were missed by the land surveyor. All of these points were located in the field for validation by a UXO technician. QA validation results were incorporated into the GIS database. Once all of the validated anomalies were plotted, a clear pattern emerged that allowed delineation of where the actual targets for the 81 mm mortars were located. This, in turn, allowed anomaly prioritization where some uncertainty remained as to the source. Efforts were then focused on validating selected anomalies that were identified by the contractor as "junk" points within these anomaly clusters.

4.6.9 Conclusions

By building QA measures into each stage of the project, the Guard was able to quantify detection efficiency, quantify positional accuracy, and reduce false positives. Results from the Diamond Springs and Guthrie Road investigations are summarized in Table 4-1.

Table 4-1. Summary of findings

Site	Percentage of emplaced rounds detected	Mean positional accuracy (cm)	True:false positives
Diamond Springs Area	94.7	72	1:10 (n=370)
Guthrie Area	100	20	1:10 (n=840)

4.6.9.1 Quantifying Detection Efficiency

Emplaced ordnance allows a simple, direct, and inexpensive means to estimate detection efficiency. Respectively, 19 and 31 rounds were emplaced for Diamond Springs and Guthrie Road sites. The number emplaced was based on the availability of representative ordnance and a desire to have a sample size that would constitute 10% or more of the total number of intact rounds recovered from each site. The contractor correctly classified 18 of the 19 emplaced rounds at Diamond Springs as ordnance and all 31 emplaced rounds at Guthrie Road.

4.6.9.2 Quantifying Positional Accuracy

Positional accuracy was determined by measuring the distance between the item and the survey flag position. There will always be a small, random error associated with the position of the survey flag due to survey error. Results indicate that this error is negligible. Positional accuracy on Diamond Springs was generally within 1 m of the survey flag. Positional accuracy of 1 m was found to be sufficient to resolve nearly all geophysical anomalies at Diamond Springs, Uncertainty increased sharply when positional accuracy exceeded 1 m. At Guthrie Road, the DGPS positioning allowed for a mean positional accuracy of less than 25 cm. Positional accuracy greater than 50 cm would have greatly increased validation time and uncertainty due to shrapnel levels.

4.6.9.3 Reducing False Positives

False positives were able to be reduced to under 10:1 without a concomitant decline in detection efficiency. Several factors are believed to have influenced this result. Care was taken to match the technology to site conditions and target parameters and selected a proven geophysical technology operated by an experienced geophysical contractor. Surface clutter was reduced through surface sweeps. Calibration grids were established using representative ordnance and emplaced inert ordnance on the site, providing an immediate and obvious incentive to the geophysical contractor to carefully evaluate each anomaly. Finally, detailed performance metrics data were collected and shared with the geophysical contractor.

5. SUMMARY AND CONCLUSIONS

In summary, the ultimate success of an MR project depends on the quality of the work performed. This document approaches quality as "conformance to requirements." Therefore, to ensure an MR project produces a quality product, the quality requirements of the "customer" must be precisely stated and understood by everyone involved. A plan is then put into place to meet those requirements. While the time spent on such planning may initially appear unproductive and costly, the penalty for ineffective planning includes greater cost and lost time due to rework.

This document encourages a whole-system approach to planning and managing the MR project. A whole-system approach means that not just parts, but the entire system (in this case the MR project) is optimized. To do so, a process approach to plan and organize the MR project is recommended. A process approach is a powerful way to plan, organize, and manage how work activities produce value (quality) for the customer. In implementing a process approach, managers strive to systematically assure that all processes, subprocesses, and tasks are properly planned, executed, and documented.

Properly implemented, the process approach should produce a plan that identifies key processes and the interrelationship of these processes necessary to complete the MR project. The plan should also identify and contain QA and QC activities that need to be performed to ensure that each process satisfies requirements. This approach to quality planning culminates in the QAPP, a formal document that identifies the key processes and describes, in comprehensive detail, the necessary QA procedures, QC activities, and other technical activities that need to be implemented to help ensure the MR project will produce a "quality" product.

Finally, the environmental regulator must be involved in the MR planning process from the beginning to ensure that the needs of the regulator are defined adequately and addressed. Up-front planning identifies MR approaches that work well, promotes a greater understanding of the processes involved, and ensures full agreement on QA/QC activities necessary to provide confidence in the quality of the final product. The up-front, whole-system process approach to planning increases efficiency and effectiveness, provides for early detection of problems, and should reduce the cost of lost time due to rework.

The environmental regulator might not be aware of the intimate details of a geophysical survey or know if the content of a specific deliverable is acceptable (QC). However, if he or she knows what a good process looks like (QA), the environmental regulator should feel comfortable with approving the deliverable based on the process used to produce it.

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Appendix A

Response to Comments

RESPONSE TO COMMENTS

The UXO Team acknowledges the following individuals and organizations that provided valuable comments, input, and suggestions for this document's improvement.

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- U.S. Army Corps of Engineers
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- Ann Charles, New Jersey Department of Environmental Protection
- David Larsen, Utah Division of Solid and Hazardous Waste
- Nebraska Department of Environmental Quality
- Mohammed Ghazi, Georgia Environmental Protection Division
- Bonnie Buthker, Ohio Environmental Protection Agency
- Kevin Oates, U.S. Environmental Protection Agency
- John McCabe, Michigan Department of Environmental Quality
- SERDP/ESTCP
- U.S. Navy

Due to the volume of comments received and the length of the UXO Team's responses, the team has elected to house this appendix on the Web. The reader is encouraged to access the appendix at www.itrcweb.org/teampublic_UXO.asp.

Appendix B

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Appendix C

Glossary

GLOSSARY

anomaly. Any item that is seen as a subsurface irregularity after geophysical investigation. This irregularity will deviate from the expected subsurface ferrous and nonferrous material at a site (i.e., pipes, power lines, etc.).[14]

anomaly excavation. The excavation and identification of a subsurface anomaly.[6]

anomaly reacquisition. The process of returning to a location identified as having an anomaly, reproducing a geophysical response at that location, and marking the location for excavation by UXO technicians.

blind seed item. Munition or clutter item buried at a known location used to assess the detection capability of a geophysical system at test sites, geophysical prove-outs, and/or as a quality control or assurance tool during production surveys. Seeded target is also referred to as a "seeded munition."

blow in place (BIP). Method used to destroy military munitions, by use of explosives, in the location the item is encountered.[6]

clearance. The removal of military munitions from the surface or subsurface at operational ranges.[6]

Comprehensive Environmental Response, Compensation, and Liability Act (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.[14]

data quality objective (DQO). 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.[14]

digital geophysical mapping (DGM). Any geophysical system that digitally records geophysical and positioning information.

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)(2).[5]

discrimination. The ability to distinguish ordnance from fragments and other nonordnance materials based solely on the geophysical signature.[6]

electromagnetic induction. Physical process by which a secondary electromagnetic field is induced in an object by a primary electromagnetic field source.

explosive ordnance disposal (EOD). The detection, identification, field evaluation, rendering safe, recovery, and final disposal of unexploded ordnance or munitions. [14]

false positive. When the geophysical sensor indicates an anomaly and nothing is found that caused the instrument to detect the anomaly.[6]

fiducial positioning. A method of manually placing electronic markers that indicate fixed locations within a set of recorded geophysical data.

formerly used defense site (FUDS). 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 Department of Defense Environmental Restoration Program policy, the FUDS program is limited to those real properties that were transferred from DOD 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.[14]

geophysical prove-out (GPO). Before conducting a geophysical survey of an entire munitions response site, a site-specific geophysical prove-out is conducted to test, evaluate, and demonstrate the geophysical systems proposed for the munitions response. Information collected during the prove-out is analyzed and used to select or confirm the selection of a geophysical system that can meet the performance requirements established for the geophysical survey.[7]

inert. Ordnance, or components thereof, that contain no explosives, pyrotechnic, or chemical agents.[4]

mag and 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. [14]

magnetometer. An instrument for measuring the intensity of magnetic fields.[6]

man-portable. Any geophysical system that can be deployed manually, either by carrying, pushing, or towing.

military munition. All ammunition products and components produced for or used by the armed forces for national defense and security, including ammunition products or components under the control of the Department of Defense, the Coast Guard, the Department of Energy, and the National Guard. The term includes confined gaseous, liquid, and solid propellants, explosives, pyrotechnics, chemical and riot control 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. The term does not include wholly inert items, improvised explosive devices, and nuclear weapons, nuclear devices, and nuclear components, other than nonnuclear components of nuclear devices that are managed under the nuclear weapons program of the Department of Energy after all required sanitization operations under the Atomic Energy Act of 1954 (42 U.S.C. 2011 et seq.) have been completed (10 U.S.C. 101 (e)(4).[5]

munition constituents. Any materials originating from unexploded ordnance, discarded military munitions, or other military munitions, including explosive and nonexplosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions. (10 U.S.C. 2710 (e)(4)).[5]

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 (UXO), as defined in 10 U.S.C. 2710 (e)(9); (b) discarded military munitions (DMM), 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.[14]

munitions response. Response actions, including investigation, removal and remedial actions to address the explosives safety, human health, or environmental risks presented by unexploded ordnance (UXO), discarded military munitions (DMM), or munitions constituents (MC).[14]

noise. Noise is commonly divided into sensor noise and environmental noise. Sensor noise is the fluctuation in sensor output in the absence of an external signal and is generally dominated by noise in the sensor electronics. Environmental noise captures other external sources that also compete with the signal of interest. These sources can include electromagnetic interference, geological noise, or other types of clutter. In the case of munitions detection, environmental noise is generally the dominant contributor to the overall noise of the system.[7]

open burning. The combustion of any material without (1) control of combustion air, (2) containment of the combustion reaction in an enclosed device, (3) mixing for complete combustion, and (4) control of emission of the gaseous combustion products.[6]

ordnance. Weapons of all kinds, including bombs, artillery projectiles, rockets and other munitions, military chemicals, bulk explosives, chemical warfare agents, pyrotechnics, explosive waste, boosters, and fuzes.[4]

projectile. An object projected by an applied force and continuing in motion by its own inertia, as mortar, small arms, and artillery projectiles. Also applied to rockets and to guided missiles.[6]

quality assurance (QA). QA refers to the processes used to create the deliverables. QA activities ensure that all processes are defined and appropriate. A QA review focuses on the process elements of a project (e.g., are requirements being defined at the proper level of detail?). Examples of QA activities are identifying methods, developing requirements, problem trend analysis, and process improvement. Examples of QA tools are process checklists and project audits. QA evaluators can be a manager, client, or even a third-party auditor.

quality control (QC). The techniques or activities designed to evaluate a completed task or product. QC activities focus on finding defects in specific deliverables. In effect, QC is determined by the comparison of a product against the requirements that were developed for the product before the product existed. Examples of QC include walkthroughs, testing, inspections, and checkpoint reviews. Typical QC steps are problem identification, problem analysis, problem correction, and feedback to QA. QC tasks are usually carried out by those directly associated with the production of a product.

range. Designated land and water areas set aside, managed, and used to research, 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. (40 CFR 266.601) A recent statutory change added airspace areas designated for military use in accordance with regulations and procedures prescribed by the Administrator of the Federal Aviation Administration. (10 U.S.C. 101 (e)(3))[6]

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*)[14]

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.[14]

signal-to-noise ratio (SNR). The signal strength and system noise are often combined in the SNR. The target's signal strength and the noise are reported in the operating units of the instrument, i.e., nanoteslas (nT) for a magnetometer and millivolts (mV) for an electromagnetic instrument. The SNR is the ratio of these two metrics (target strength divided by noise level) and is a dimensionless quantity. In general, SNRs of a minimum of 2–3 are required for reliable detection.[7]

site preparation. This process typically includes a MEC surface removal to remove any MEC potential hazards to the survey team, removal of surficial metallic objects to eliminate potential interference, clearance of vegetation, and establishment of survey grids and control points.[7]

Standardized Test Site. Established technology demonstration sites at both Aberdeen Proving Ground and Yuma Proving Ground for users and developers to define the range of applicability of specific UXO technologies, gather data on sensor and system performance, compare results, and document realistic cost and performance information.[11]

target. Target is typically used to denote two different concepts: (1) the individual munitions item that one is attempting to detect and (2) the aim point of a weapons system at which large concentrations of munitions are typically found (i.e., an aiming circle for aerial bombing). In this document, "target" refers to the first definition.[1]

unexploded ordnance (UXO). Military munitions that (a) have been primed, fused, 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))[14]

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Appendix D

Acronyms

ACRONYMS

AAR	after-action report
AQAPS	Automated Quality Assessment Program System
BIP	blow in place
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DDESB	Department of Defense Explosives Safety Board
DFW	definable feature of work
DGM	digital geophysical mapping
DGPS	differential GPS
DMM	discarded military munitions
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DQO	data quality objective
ECOS	Environmental Council of the States
EDM	electronic distance measuring
EMI	electromagnetic induction
EOD	explosive ordnance disposal
EPA	U.S. Environmental Protection Agency
ERIS	Environmental Research Institute of the States
ESS	Explosives Safety Submission
ESTCP	Environmental Security Technology Certification Program
FUDS	formerly used defense site
GIS	geographic information system
GPO	geophysical prove-out
GPS	global positioning system
ITRC	Interstate Technology & Regulatory Council
ITS	Instrument Test Strip
JPG	Jefferson Proving Ground
MC	munitions constituents
MD	munitions debris
MDAS	material documented as safe
MEC	munitions and explosives of concern
MPPEH	material potentially presenting an explosive hazard
MR	munitions response
NCP	National Contingency Plan
NPL	National Priorities List
OU	operable unit
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
QMP	Quality Management Plan
RCRA	Resource Conservation and Recovery Act
RRD	range-related debris
SERDP	Strategic Environmental Research and Development Program
SNR	signal-to-noise ratio

SOP	standard operating procedure
TSDF	treatment, storage, and/or disposal facility
UFP-QAPP	*Uniform Federal Policy Quality Assurance Project Plans*
USFWS	U.S. Fish and Wildlife Service
UXO	unexploded ordnance
VSP	Visual Sample Plan