RANGE ENVIRONMENTAL VULNERABILITY ASSESSMENT (REVA)

REFERENCE MANUAL

For Baseline Assessments

FINAL

May 2009

Prepared by:

Headquarters Marine Corps
2 Navy Annex
Washington, D.C. 20380-1775

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

This page left intentionally blank

1.0 INTRODUCTION

Military installations, including operational range and training areas, serve as realistic testing and training platforms that provide varied, realistic, and reusable land, air, and sea resources suitable to fulfill Marine Corps Title 10 responsibilities. National, state, and local processes regulating frequency spectrum, airspace, natural resources, and human health and safety combine to constrain the timing, location, and frequency of testing and training readiness activities on operational ranges and training areas. The Senior Readiness Oversight Council (SROC) identified these constraints, or encroachment issues, as significant readiness concerns.

Encroachment problems arise from two primary sources: conflicting land uses and restricting regulations. Conflicting incompatible land uses both near the installation and at locations distant from the installation limit low-level flying routes and target areas. The conflicting land uses usually are referred to by the military as urban sprawl and by others as mission expansion. Federal, state, regional, and local regulations restrict the use of land, airspace, and communication frequencies. The most common regulations are those associated with protecting human health and safety, natural resources, and cultural resources.

The United States (U.S.) Marine Corps defines encroachment as "any non-DoD [Department of Defense] action or constraint that causes or may cause the loss of, or restriction to, the use of land, air frequency and sea maneuver areas required or planned by the Marine Corps to maintain readiness" (U.S. Marine Corps, 1987).

The Range Environmental Vulnerability Assessment (REVA) program is a proactive and comprehensive program designed to support the Marine Corps' environmental range sustainment initiative. The REVA process investigates and analyzes installation and operational range encroachment from potential environmental regulations relating to munitions constituent (MC) contamination. REVA determines whether a release or substantial threat of a release of MC of concern from an operational range or range complex area to an off-range area creates an unacceptable risk to human health or the environment. REVA's detailed environmental assessment presents insights into MC migration, which could create encroachment pressures on range complexes, and assists installation and range managers in formulating range sustainability strategies and environmental investment decisions.

The intent of the REVA Reference Manual is to document the baseline assessment process conducted at each installation. The process detailed in this manual is a standard, well-documented, and defensible process that was used to perform the initial baseline assessments of the operational ranges and also supports a consistent and efficient approach to analysis across the Marine Corps.

1.1 BASELINE AND SUBSEQUENT ASSESSMENTS

This Reference Manual outlines the REVA process for the baseline assessments conducted across the Marine Corps. The baseline assessments were performed and funded by Headquarters Marine Corps (HQMC) to get an initial evaluation of the environmental conditions for all operational ranges on Marine Corps installations. A baseline assessment will also be conducted when a new operational range area is added to an installation.

Subsequent assessments to be performed will update the baseline assessment and provide a check as to whether the baseline assessment still represents conditions at the operational ranges relating to the potential release of MC to off-range areas. A subsequent assessment will be conducted, at a minimum, every five years from the baseline assessment or whenever significant changes occur that affect determinations made during the previous assessment (e.g., there is a major orientation change in an operational range, the operational range undergoes a modification).

Note that the Marine Corps (specifically, Training and Education Command [TECOM]) purposely separates operational ranges and training areas. For this document, the term "operational range" implies operational ranges and training areas. See Appendix A for key terms and abbreviations used throughout the Reference Manual.

1.1.1 Stakeholder Involvement

The DoD Instruction (DoDI) 4715.14 provides the key elements and responsibilities for the operational range assessment program; however, it provides limited guidance regarding interactions with the public or stakeholders during the planning and execution of operational range assessments. A memorandum dated 15 August 2006 and signed by Assistant Deputy Under Secretary of Defense (Environmental, Safety, and Occupational Health) Mr. Alex Beehler presents the guidelines for DoD-regulator interactions for operational range assessments. DoDI 4715.14 requires the reporting of an off-range release that has the potential to impact human health or the environment and requires that documentation of findings be made available to stakeholders, which the 15 August 2006 memorandum restates. Absent an "unacceptable risk," operational ranges generally are not subject to regulation; therefore, the Marine Corps will plan and conduct the operational range assessments as a part of the Marine Corps' overall range sustainment initiatives. However, the Marine Corps has a desire to keep stakeholders, when interested, informed about plans, schedules, and progress of the assessments. Therefore, HQMC developed REVA Overview and Modeling fact sheets and a REVA Frequently Asked Questions document (Appendix B), which can be provided by range/installation points of contact (POCs) regarding the operational range assessments. The Marine Corps believes that the most appropriate way to facilitate information exchange with stakeholders is for the appropriate range/installation POCs to interact with the appropriate stakeholders, as needed. At a minimum, the Marine Corps will provide all draft final assessment reports to identified regulators 60 days prior to report finalization.

Interaction with stakeholders may vary from only providing the documentation of findings (as required by DoDI 4715.14 and specified in the 15 August 2006 memorandum) to communicating more directly with stakeholders. More direct communication may include briefings or providing other quality-reviewed assessment documentation for informational purposes. During the baseline assessments, the level of detail and data provided were left to the appropriate range/installation Marine Corps POC's discretion based on stakeholder relationships.

1.2 SCOPE AND APPLICABILITY

The scope of the REVA program includes Marine Corps operational ranges located within the United States and overseas. Operational ranges (as defined in 10 United States Code [U.S.C.] 101(e)(3)) include, but are not limited to, fixed ranges, live-fire maneuver areas, small arms ranges (SARs), buffer areas, and training areas where military munitions are known to be or suspected to have been used. Operational ranges exclusively used for small arms training are being evaluated qualitatively under REVA using the Small Arms Range Assessment Protocol (SARAP; Appendix C) developed specifically for REVA. The assessment of SARs is discussed more specifically later in this manual. Skeet/trap ranges were excluded from the baseline assessment if only used for recreation. Operational ranges that are permitted under an already established regulatory program (i.e., Resource Conservation and Recovery Act [RCRA] Subpart X permits) were also excluded since they are monitored under a specific regulatory program. The Marine Corps has two such ranges that are permitted for all pertinent requirements. They will continue to be evaluated as part of RCRA compliance and not within the REVA program. Data pertaining to water ranges were collected during the baseline assessments, but the specific assessment processes for water ranges have not been defined.

The REVA program applies to all Marine Corps operational ranges; however, each portion of this manual may not be applicable to every installation. For example, not all installations have the same types of operational ranges or organizational structure. The subject areas covered in this Reference Manual are intended to inform the user about the applicable requirements and provide the processes and materials used to perform a thorough analysis under the REVA program. This manual is a comprehensive tool used to identify range activities that required closer examination.

REVA does not apply to other than operational ranges; these ranges are addressed under the Munitions Response Program.

1.3 DOD POLICY AND PLANNING DOCUMENTS

The DoD has issued several policy, guidance, and planning documents that drive and guide the need to assess operational ranges with respect to potential MC migration from operational ranges, as well as encroachment factors such as endangered species and critical habitat, unexploded ordnance (UXO) and munitions, frequency encroachment, maritime sustainability, airspace restrictions, air quality, airborne noise, and urban growth. The various policy drivers and guidance documents establishing the need for the REVA program include DoD Directive (DoDD) 3200.15, DoDD 4715.11, DoDD 4715.12, and DoDI 4715.14, which are summarized below.

1.3.1 DoDD 3200.15 Sustainment of Ranges and Operating Areas (OPAREAS) (January 2003)

DoDD 3200.15 requires that "ranges and OPAREAS shall be managed and operated to support their long-term viability and utility to meet the National Defense Mission. All functional elements of installation, range, and OPAREAS management shall be integrated fully to support the DoD testing and training missions."

1.3.2 DoDD 4715.11 [4715.12] Environmental and Explosives Safety Management on Operational Ranges within the United States [Outside the United States] (May 2004)

DoDD 4715.11 and DoDD 4715.12 require the DoD "to ensure the long-term viability of operational ranges while protecting human health and the environment… to enhance the ability to prevent or respond to a release or substantial threat of a release of MC from an operational range to off-range areas."

1.3.3 DoDI 4715.14 Operational Range Assessments (November 2005)

DoDI 4715.14 establishes the procedures to perform operational range assessments. The instruction assists the DoD in: 1) determining whether there has been a release or a substantial threat of a release of MC of concern from an operational range to an off-range area, 2) determining whether a release or substantial threat of a release of MC of concern from an operational range to an off-range area creates an unacceptable risk to human health or the environment, and 3) enhancing the DoD's ability to prevent or respond to such a release.

1.3.4 National Defense Authorization Act (NDAA) for Fiscal Year (FY) 03, Section 2811 and Amended FY06 Section 2822

The FY03 NDAA Section 2811 and amended for FY06 Section 2822 describe agreements to limit encroachment and other constraints on military training, testing, and operations. The Act states that the DoD must

> address the use or development of real property in the vicinity of a military installation for purposes of 1) limiting any development or use of the property that would be incompatible with the mission of the installation or 2) preserving habitat on the property in a manner that is compatible with environmental requirements; and may eliminate or relieve current or anticipated environmental restrictions that would or might otherwise restrict, impede, or otherwise interfere, whether directly or indirectly, with current or anticipated military training, testing, or operations on the installation.

1.3.5 Executive Order (EO) 12580 Superfund Implementation (January 1987)

This EO delegates the President's Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) response authority to the DoD components for releases of hazardous substances from DoD facilities.

1.3.6 DoD Perchlorate Handbook Revision 1, Change 1 (August 2007)

The DoD Environmental Data Quality Workgroup prepared the DoD Perchlorate Handbook to ensure that cost-effective and consistent approaches are used across the DoD for sampling and testing activities involving perchlorate, that collected data are of the quality necessary to support decision-making, and that information disseminated to the public associated with perchlorate sampling and testing complies with DoD guidelines. The Office of the Secretary of Defense has issued additional guidance to augment the DoD Perchlorate Handbook entitled *Actions in Response to Perchlorate Releases,* dated September 21, 2007. The Marine Corps has also issued additional guidance in the *Marine Corps Perchlorate Sampling and Management Policy*, dated April 11, 2006.

1.3.7 Munitions Action Plan (Approved April 2002)

The Operational and Environmental Executive Steering Committee for Munitions (OEESCM) developed the Munitions Action Plan to outline a strategy to address issues and challenges associated with the lifecycle management of military munitions. To implement the Munitions Action Plan, the OEESCM established several subcommittees, including the Range and Munitions Use Subcommittee (RMUS). The RMUS's Objective 1 is to "develop a coordinated DoD plan to obtain data, assess current range conditions, and estimate the environmental impacts of munitions use on operational ranges." This committee continues to meet regularly to coordinate issues associated with operational ranges within DoD.

1.3.8 SROC Sustainable Range Action Plan

The SROC identified encroachment issues affecting military training and testing, including endangered species and critical habitat, UXO and munitions, frequency encroachment, maritime sustainability, airspace restrictions, air quality, airborne noise, and urban growth (SROC, 2000).

1.3.9 NDAA for FY04, Section 320

The FY04 NDAA Section 320 requires the DoD to prepare a report regarding the impacts of civilian community encroachment and certain legal requirements on military installations and ranges, including:

- compliance with state implementation plans for air quality under Section 110 of the Clean Air Act,
- compliance with the Solid Waste Disposal Act (42 U.S.C. 6901 et seq), and
- compliance with the CERCLA (42 U.S.C. 9601 et seq).

Section 320 requires the DoD to submit a report containing the results of an encroachment analysis and response plan. Section 320 also requires yearly updates to be issued from FY07 through FY10 on the progress made to implement the encroachment response plan.

1.3.10 NDAA for FY03, Section 366

The FY03 NDAA Section 366 requires the DoD to submit annual reports on the operational condition of training and test ranges, current and future training range requirements, and the ability of DoD resources to meet those requirements.

1.4 ORGANIZATION OF REFERENCE MANUAL

This REVA Reference Manual addresses interdisciplinary/multifunctional Marine Corps activities and organizations involved with the use of military munitions on operational ranges. Typical functional areas or organizations involved with the process include, but are not limited to, Environmental Affairs Department (EAD) / Natural Resources Environmental Affairs (NREA) Office; Facilities, including Real Estate, Planning/Development, Engineering, and Facilities Maintenance; Geographic Information System (GIS) Office; Range Management / Range Control; Community Plans and Liaison Office (CPLO) / Public Affairs Office (PAO); Air Traffic Control (ATC); Explosive Ordnance Disposal (EOD); and other offices, such as Library, Base Historian, and Explosive Safety.

This document presents the process that was used to conduct the baseline operational range assessments under the REVA program. The process outlined in this Reference Manual typically was followed sequentially. Each section is described below. A flow diagram of the REVA process is shown in Figure 1.4-1.

- Section 1 *Introduction* outlines the directives and purposes behind the necessity for conducting operational range assessments.
- Section 2 *Assessment Preparation* outlines the preparation conducted for the baseline assessment.
- Section 3 *REVA Data Collection Manual* details information that typically was obtained from various sources for the assessments.
- Section 4 *Data Extraction* details the data required to do the assessments.

- Section 5 *Conceptual Site Model* (CSM) describes items needed to complete a CSM.
- Section 6 *Fate and Transport Modeling* describes the modeling procedures that were followed.
- Section 7 *Data Analysis* outlines how data, including model results, were reviewed and analyzed.
- Section 8 *Presentation of REVA Results* documents how conclusions and results from the analysis were presented.

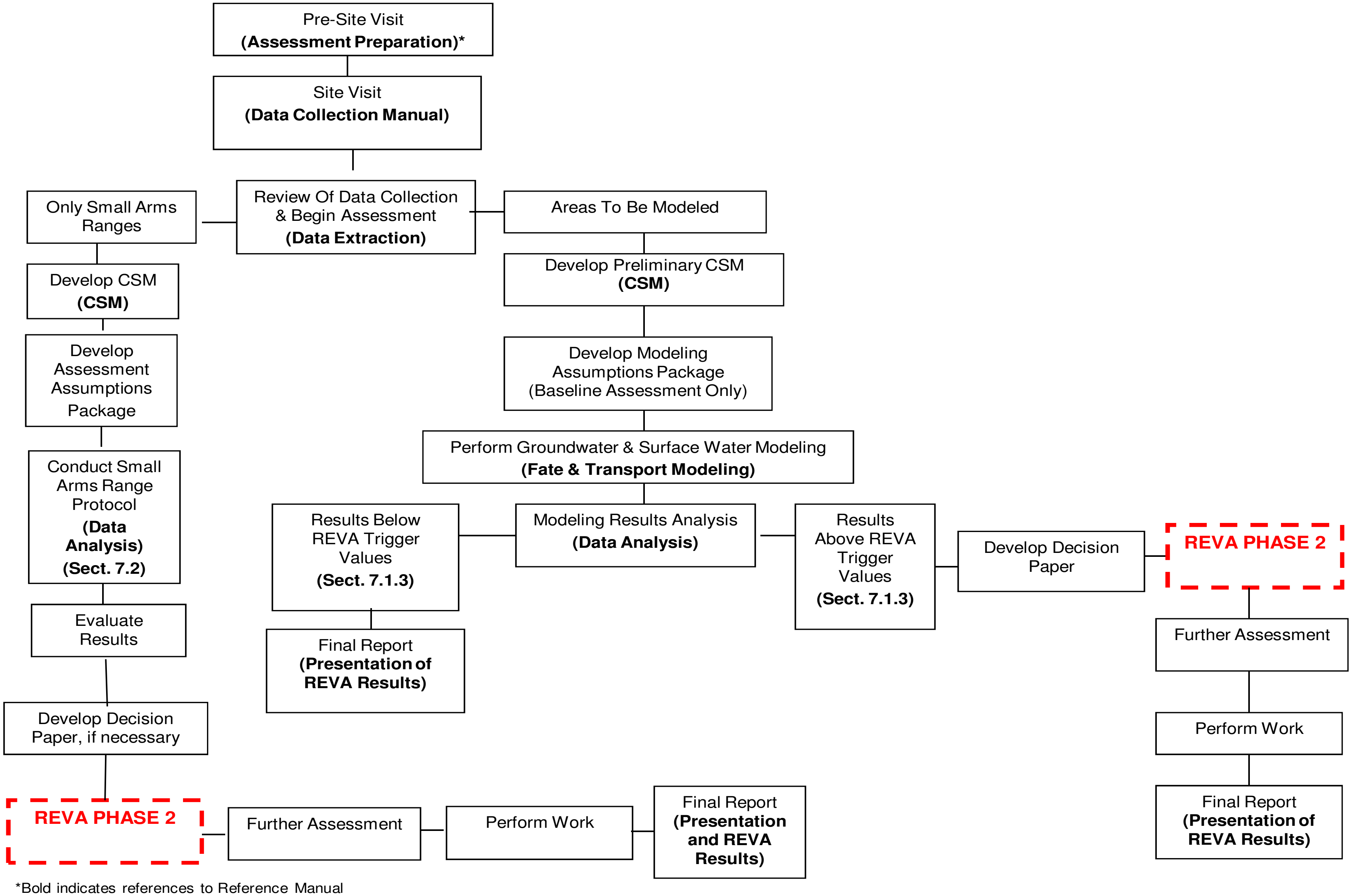


Figure 1.4-1: REVA Process Flow Diagram

2.0 ASSESSMENT PREPARATION

This section outlines the REVA preparation activities that were conducted for the baseline assessments. Baseline assessments were performed and funded by HQMC for consistency in approach and technical processes.

2.1 PRE-SITE VISIT

2.1.1 REVA Team

The REVA Team was responsible for the implementation of the REVA process through data collection and extraction, modeling, data analysis, and development of the REVA report. The Team was composed of installation personnel, members of HQMC, TECOM, and contractor personnel hired by HQMC.

The REVA Team consisted of people who had experience in the following areas: environmental engineering, hydrology, hydrogeology, groundwater and/or surface water fate and transport modeling, military munitions, natural resources, and cultural resources. A Team Leader was designated from the contractor personnel for each installation assessment. The Team Leader's responsibilities included:

- overseeing the REVA Team and ensuring the REVA process was implemented appropriately for the installation;
- assigning team members' responsibilities for specific departments, interviews, document collection, and other tasks;
- communicating with HQMC, TECOM, and installation team members regarding the status and interim outcomes and/or deliverables; and
- coordinating development of conclusions and the REVA report.

2.1.2 Document Review

In order to have an adequate understanding of the installation and operational ranges, the following base-specific documents typically were reviewed in advance of performing the REVA:

- Mission-Capable Ranges, Training Range Sustainment Planning and Training Range Inventory (most current update), pursuant to FY 2003 NDAA Section 366 information request (Section 366 report)

- TECOM Range Capability Document
- Marine Corps Operational Range Inventory List
- Archive Search Report (ASR)
- Preliminary Range Assessment (PRA) report
- Range Intranet Navy Facility Asset Data Storage (INFADS) data
- Available operational range maps / aerial photographs / historical photographs
- Marine Corps Orders and policy applicable to REVA

The REVA Team reviewed these data prior to commencing the assessment to better understand the installation and ranges prior to data collection, as well as to identify any existing data gaps.

2.1.3 Read-Ahead Letter

As part of the baseline process, HQMC submitted a read-ahead letter to the Office of the Commanding General (CG) / Commanding Officer (CO) of the installation approximately 30 days prior to the site visit. The letter described the REVA process and requested the scheduling of an in-brief for the CG/CO. The letter also requested information from POCs at major installation offices and requested their attendance. These offices included, but were not limited to, the EAD/NREA Office; Facilities, including Real Estate, Planning/Development, Engineering, and Facilities Maintenance; GIS Office; Range Management / Range Control; CPLO/PAO; ATC; EOD; and other offices, such as Library, Base Historian, and Explosive Safety.

2.1.4 In-Brief

As part of the baseline process, HQMC provided a REVA process in-brief to the CG/CO (or designee) prior to commencing the site visit. Representatives from each office involved in REVA attended the in-brief, if possible.

2.1.5 Operational Range Windshield Tour

During the baseline assessment, the installation POC coordinated (when possible) a windshield tour of operational ranges at the installation. The operational range tour gave the REVA Team an orientation of the range setting and context for assessment of vulnerabilities at the particular installation.

This page left intentionally blank

3.0 REVA DATA COLLECTION PROCESS

The REVA provides a snapshot of the environmental conditions of the operational ranges at an installation associated with potential MC migration. Each assessment was based upon readily available data that were collected through various sources, including interviews and document searches across various installation offices.

The data collection process was organized by functional office area based on a typical installation; however, this required modification depending on the organization of the specific installation. In order to assist in the data extraction process described in Section 4, color-coding was provided in this data collection manual (DCM). Red color codes represented information needed to determine MC loading rates on the operational ranges, blue represented environmental information needed for input into the groundwater and surface water models, and green represented data related to other range encroachment issues (e.g., endangered species, noise).

The REVA data collection process is depicted in Figure 3.0-1. The data collection process followed two basic tracks: the range training and operations track and the environmental track. The two-track process was designed to ensure adequate collection of necessary information from each of the departments. Each of the departments visited, interviews conducted, and documents obtained are described in the following sections. The sections are set up as shown in Figure 3.0-1. The figure also shows a "stop" in the process after some offices were visited. The stop was a recommended halt in the data collection process for the Team to assess what information was known and to compare information collected from each of the tracks prior to continuing data collection in order to avoid duplication of data collection and to compare knowledge learned thus far. Stops occurred anytime that it was necessary to assess what information had been collected and what information still needed to be collected. The organization of offices was identified based on prioritizing necessary data to assist the Team. Data collected from the beginning of the tracks sometimes helped alleviate the possibility of duplication, or this information was necessary to proceed with additional data collection at other departments in the tracks.

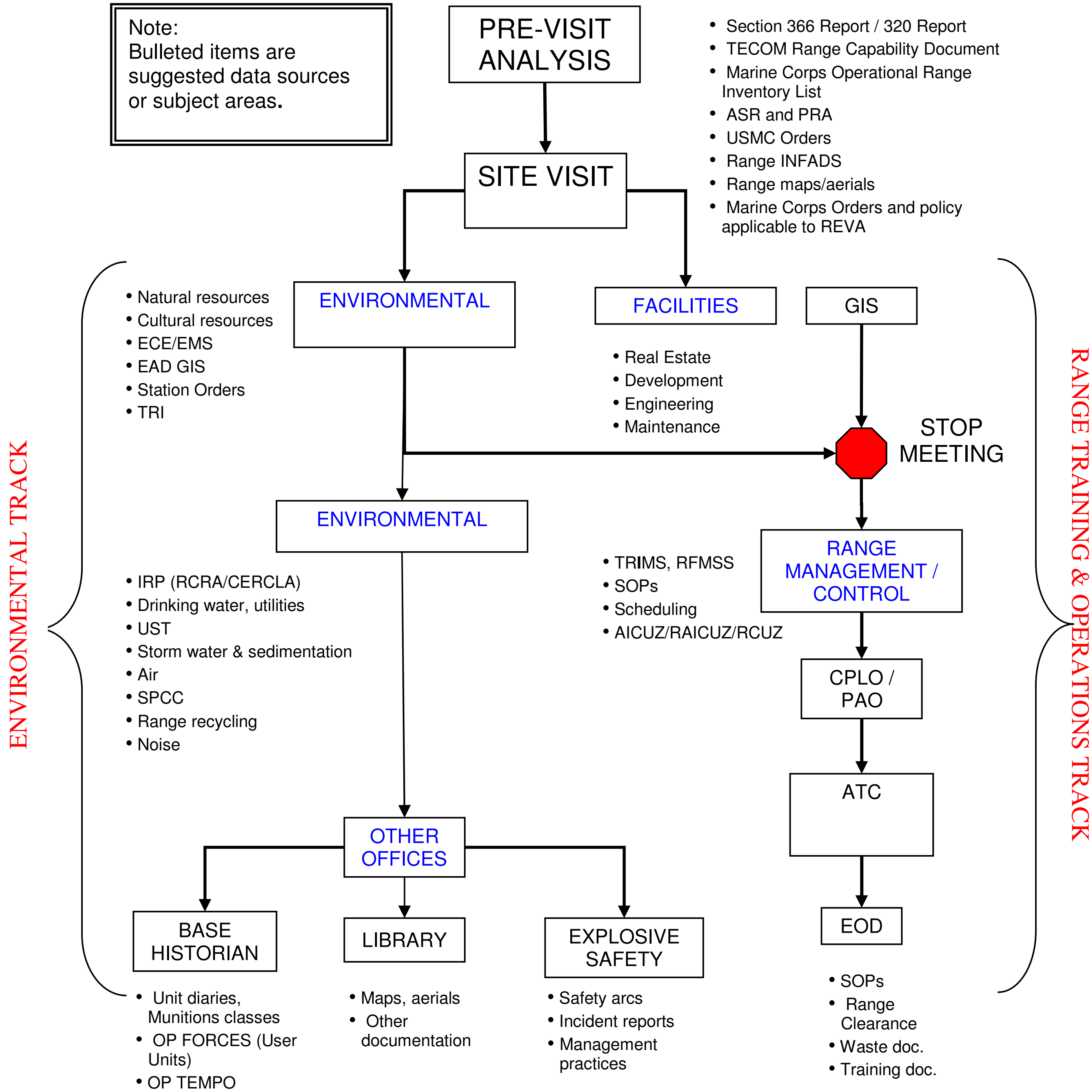
Since installations are organized and managed differently, not all of the identified departments needed to be visited and interviewed to collect necessary data. This section was created to identify all departments, documents, and information that could be possible sources of data in order to complete the REVA process at an individual installation; however, all identified information may not have been necessary to complete an assessment at a given installation. The DCM was intended to be used as a guide.

3.1 DATA COLLECTION FOR SUBSEQUENT ASSESSMENTS

Subsequent assessments will be based on data collected during the baseline assessment and additional readily available data obtained through various sources, including interviews and document searches across several installation offices.

The baseline assessments considered a thorough review of the historical usage of the operational ranges to estimate the potential amounts of MC deposited on the operational ranges over time (MC loading). The goal of the baseline assessment process was to estimate the MC loading from the time the operational range or training area was first used for military munitions related training through the time the data were collected. For subsequent assessments, the baseline assessment should be reviewed to understand the time scale covered by the baseline assessment. Subsequent assessments can use the baseline assessment as a starting point and account for operational range usage from the end of the baseline to the time when the subsequent assessment is conducted. In cases where additional operational range area is added that was not assessed previously, an exhaustive review of the historical data should be performed to ensure that historical MC loading is accounted for. For the baseline assessments, the historical operational range usage data were extracted from the ASR and PRA report.

The data collection process for subsequent assessments can follow the general process used for the baseline assessment. Information and data reviewed during the baseline assessment can serve as a foundation for subsequent assessments. The DCM can be used to request any updated information and/or data since the baseline was completed.



Notes:
AICUZ—Air Installations Compatible Use Zones
ECE/EMS—Environmental Compliance Evaluation/Environmental Management System
IRP—Installation Restoration Program
OP FORCES—Operating Forces
OP TEMPO—Operating Tempo
RAICUZ—Range Air Installation Compatible Use Zones
RCUZ—Range Compatible Use Zone
RFMSS—Range Facilities Management Support System
SOP—Standard Operating Procedure
SPCC—Spill Prevention Control and Countermeasure
TRI—Toxics Release Inventory
TRIMS—Target and Range Information Management System
TRP—Toxic Release Point
USMC—United States Marine Corps
UST—Underground Storage Tank

Figure 3.0-1: REVA data collection Process

3.2.1 Natural Resources

Installation: ______________________________ Date: ____________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: To determine impact of range operations on natural resources, including threatened and endangered (T&E) species, and to what extent training activities are affected by these sites. To obtain pertinent documentation, studies, and reports.

Documents/Data to Obtain:

- ☐ National Environmental Policy Act documents
- ☐ Wetland delineations (map / GIS files)
- ☐ Integrated Natural Resource Management Plans (INRMPs)
- ☐ Biological opinions
- ☐ Specific studies (e.g., rare species inventories, biological assessments)

Pertinent Questions:

1. Are wetlands, natural resources (e.g., streams, lakes), and/or cultural, historical, or archaeological sites located on or adjacent to the operational range(s) adversely impacted by range operations?

2. How do these sites affect training activities on operational ranges?

3. What is the protocol for the natural resources impact analysis?

4. List the cultural/historical/archaeological surveys performed for the sites located on or adjacent to the operational ranges.

5. What other pertinent natural resource issues are applicable to the operational range(s) (e.g., migratory birds, anadromous fish, noxious weeds, wild and scenic rivers, designated wilderness)?

6. What past and/or present restoration or mitigation projects are being undertaken on the installation within or adjacent to the operational ranges?

7. List the state, federal, and environmental groups who have expressed concern for natural resources and/or impact to natural resources as a result of operational range activities.

<u>T&E Species</u>

8. What, if any, T&E species reside on or migrate into the operational ranges?

9. How is T&E species management addressed and implemented in the INRMP?

10. What restrictions are imposed on operational range utilization by the management of T&E species?

11. For which T&E species have the U.S. Fish and Wildlife Service (USFWS) / National Oceanic and Atmospheric Administration (NOAA) fisheries authorized incidental take?

12. List any biological opinions that have been issued by the USFWS or National Marine Fisheries Service.

13. What academic or independent research has been conducted for T&E species or suitable habitat on the operational range areas?

14. List any ecorisk assessments that have been completed for the operational range area.

15. List any designated critical habitat located in the operational range area.

16. Is there habitat for T&E species that currently is not inhabited?

    a. If yes, is this habitat identified in the INRMP?

17. What procedures are in place to protect species from disturbance resulting from operational range operations? Do these procedures include periodic monitoring?

18. List any habitat surveys that have been conducted and any vegetation assemblages that have been recorded for the operational range area.

19. Identify all protected species that may be residents or seasonal visitors within the operational range area.

20. How does the INRMP, as concurred by the USFWS and the state, provide a benefit to all listed species?

3.2.2 Cultural Resources

Installation: ______________________________ Date: ___________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: To determine impact of range operations on historical, cultural, and archaeological sites and to what extent training activities are affected by these sites. To obtain pertinent documentation, studies, and reports.

Documents/Data to Obtain:

☐ Integrated Cultural Resource Management Plans

Pertinent Questions:

1. Are cultural, historical, or archaeological sites located on or adjacent to the operational range(s) adversely impacted by range operations?

2. How do these sites affect training activities on operational ranges?

3. What is the protocol for cultural resources impact analysis?

4. List the cultural/historical/archaeological surveys performed on or adjacent to operational ranges.

5. List the state, federal, and environmental groups who have expressed concern for cultural resources and/or impact to cultural resources as a result of operational range activities.

3.2.3 TRI

Installation: ______________________________ Date: ___________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: To determine the process of gathering the expenditure data for TRI reporting and to get a copy of the TRI export data for all reporting years and all ranges.

Documents/Data to Obtain:

- ☐ Expenditure data used to generate the TRI. Get data for as many years as available. (Verify that Range Control has older data.)
- ☐ Copies of Emergency Planning and Community Right-to-Know Act (EPCRA) related documents that pertain to the military munitions or operational ranges (e.g., reports)

Pertinent Questions:

1. Was TRI reporting submitted for military munitions use for all years starting in 2001 for all operational ranges?

2. How do the TRI “facilities” relate to the operational ranges?

3. Have reporting deadlines been met for all EPCRA reporting requirements associated with military munitions (including emergency release notifications and Sections 311, 312, and 313 reporting)?

4. What concerns do the regulatory agencies and/or the public have regarding TRI releases associated with operational range activities reported under EPCRA?

5. Have any EPCRA compliance requirements from DoD or a regulatory agency negatively impacted operational range activities?

6. Do you anticipate future activities (such as range activities) that may increase TRI quantities/reporting?

3.2.4 RCRA Corrective Action / IRP

Installation: ______________________________ Date: ___________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: To obtain information for modeling development and to determine if regulators may have involvement on the operational ranges.

Documents/Data to Obtain:

- ☐ Preliminary Assessments / Feasibility Studies
- ☐ RCRA Facility Assessments (RFAs) / RFA Investigations
- ☐ Remedial Design Reports
- ☐ Corrective Measures Studies
- ☐ Annual Hazardous Waste Report
- ☐ RCRA monitoring
- ☐ Long-term monitoring and sampling data
- ☐ CSMs
- ☐ Preliminary Pathways Analysis
- ☐ Decision Documents
- ☐ Land Use Control Documents
- ☐ Ecological/Human Health Risk Assessments
- ☐ Underground Storage Tank (UST) program documents
- ☐ Baseline groundwater quality documents
- ☐ RCRA Permits (especially Subpart X)

Pertinent Questions:

1. Are any operational ranges on or near a CERCLA site or National Priorities List site? If yes, where are they? What are the constituents associated with the site? Have you sampled for or identified MC?

2. Do you currently have or have you ever applied for a Subpart X permit? Do you have an Interim Status Permit? If yes to either, is the permitted facility located on an operational range?

3. Are any solid waste management units located on or adjacent to any operational ranges? If yes, where and which ones? What are the constituents associated with the site? Have you sampled for or identified MC?

4. Are you currently performing a RCRA corrective action / CERCLA response at any operational range? If yes, list which ones. Tell us about any investigation/ remediation occurring on operational ranges.

5. Provide groundwater characteristics, such as physical properties, depth to groundwater, and chemical quality, particularly in areas on or adjacent to operational ranges.

6. Provide information on the entire groundwater monitoring system at the installation if any are associated with the operational ranges (i.e., number of groundwater-bearing zones, aquifers used for potable water, and locations of wells).

7. Provide description of geology/hydrology at the installation associated with the operational range areas (based on available data, if any exist).

8. How do Range Management/ Range Control and EOD coordinate with your range control regarding operational range clearance?

9. How frequently are the operational ranges cleared of range debris? What is the process for performing range clearance?

10. What potential/known receptors have been identified as a result of RCRA/CERCLA releases?

11. What kind of interaction/communication/involvement exists with the Restoration Advisory Board?

3.2.5 Drinking Water Program

Installation: ______________________________ Date: ____________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: To determine extent of drinking water supply system and its vicinity to installation activities. To obtain water supply data (coordinate with Facilities).

Documents/Data to Obtain:

- ☐ Engineering Design and/or Construction Record Drawings of water supply systems
- ☐ Utilities, facilities, operation, and maintenance procedures
- ☐ Compliance Evaluation Results/Updates
- ☐ Drinking water source information

- ☐ Sampling data
- ☐ Public water supply well logs, if readily available
- ☐ Map of on- and off-installation water supply wells

Pertinent Questions:

1. What is the primary source of potable water for the installation?

2. How many drinking water production wells are present on the installation?

   a. On operational ranges?

   b. Adjacent to operational range area?

   c. What is the distance of production wells (installation) to the nearest operational range?

3. What residential, public, commercial, and/or industrial water supply wells are located within the immediate vicinity (1-mile radius) / adjacent to the installation?

3.2.6 Storage Tank Program

Installation: ______________________________ Date: ___________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: To determine whether storage tanks are present and their vicinity to operational ranges. To obtain pertinent documentation, studies, and reports.

Documents/Data to Obtain:

- ☐ UST Site Assessment Reports
- ☐ UST Remediation Reports
- ☐ Permits for USTs and/or Closure Reports
- ☐ Spill Prevention, Control, and Countermeasure (SPCC) Plans

☐ Monitoring and sampling data

☐ UST Management Plans

Pertinent Questions:

1. Are any storage tanks, aboveground or belowground, present on or adjacent to any operational range? If yes, how many? Provide range name.

2. Have any subsurface investigations been completed in association with USTs at the installation? At the operational range(s)?

3. Provide soil/groundwater physical and chemical data obtained through UST subsurface investigations.

4. Does the installation have an SPCC Plan? If so, obtain a copy (this could contribute to drainage data).

3.2.7 Storm Water / Sedimentation

Installation: ______________________________ Date: ____________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: To determine storm water and sedimentation management practices. To obtain pertinent documentation, studies, and reports.

Documents/Data to Obtain:

☐ Watershed information / Watershed Assessment Reports

☐ Storm Water Management Plan

☐ Storm Water Management / Oil-Water Separators

☐ Storm Water Pollution Prevention Plan (SWP3) / Sedimentation Control

☐ Annual Storm Water Reports

☐ Outfall data

☐ National Permit Discharge Elimination System (NPDES) Permit (Storm Water - general permits only)

Pertinent Questions:

Clean Water Act (CWA) Section 303d Information *(questions may need to be asked of several groups of people – Wastewater Treatment Plant, water, etc.):*

1. What surface water bodies exist within or adjacent to operational ranges?

2. What are the water body uses?

3. What are the water body classifications?

4. Are there any tidal actions/currents that affect the water bodies?

5. List any navigable waters that are located on the operational ranges' impact area, surface danger zone (SDZ), and/or adjacent areas.

   a. Which of the navigable waters have been identified as impaired waters (CWA Section 303d)?

6. What studies have been conducted to analyze if training activities at operational ranges affect the local watersheds?

7. Do the watersheds drain to surface water bodies that are used as a drinking water source? (What are the drainage/discharge directions?)

8. Are there any designated floodplains within the operational range area?

9. Does the installation have a Storm Water Management Plan?

10. Does the installation have an SWP3?

    a. Is the SWP3 implemented at operational ranges? If yes, how?

11. Describe any sediment dredging that is conducted on or near operational ranges.

    a. How often is dredging conducted?

    b. Describe any military munitions observed during dredging activities.

12. Describe the installation's NPDES permit(s) (for the installation-defined areas/outfalls).

a. What are the NPDES permit limits for any permitted outfalls?

b. Which of the permitted outfalls are located on or near operational ranges?

c. List any discharge areas that are not currently permitted.

3.2.8 Noise Control and Abatement

Installation: ______________________________ Date: ____________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: To assess extent of noise complaints and process by which the installation handles them. To obtain pertinent documentation, studies and reports.

Documents/Data to Obtain:

- ☐ Air Installations Compatible Use Zone Study
- ☐ Range Air Installations Compatible Use Zone (RAICUZ) Study
- ☐ Range Compatible Use Zone (RCUZ)
- ☐ Joint Land Use Study (JLUS)

Pertinent Questions:

1. How is noise monitored?

2. What are the primary noise areas that are of greatest concern related to operational ranges?

3. How are these areas being addressed (what is the process for addressing any noise complaints)?

4. What flight or other types of restrictions are imposed on training because of noise concerns?

5. How greatly does this impact training?

6. How do you coordinate with the CPLO/PAO regarding noise complaints associated with operational ranges?

7. Are you aware of any current outstanding noise complaints that are associated with operational ranges?

8. How have off-base sound attenuation measures been implemented?

9. Has the local community accepted/adopted the installation's noise impact/contours into its zoning planning?

10. Does the local government or developers/realtors have mandatory noise disclosure regulations for informing the public?

11. Is the installation in the process of acquiring land?

    a. If yes, is it a part of a buffer zone acquisition?

3.3 FACILITIES

The offices within the Facilities Department should be visited early in the data collection process to obtain data that set the foundation for the understanding of the activities performed at the installation, its property layout, future development plans, and utilities.

Data collection should take place at multiple offices within Facilities, including Real Estate, Planning/Development, Engineering, and Facilities Maintenance.

3.3.1 Real Estate

Installation: _____________________________ Date: ___________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: To gain an understanding of the real property used for operational ranges and training in terms of boundaries and ownership according to the installation's real estate records. To determine if any restrictions, use agreements, or easements impact the use of the operational range area.

Documents/Data to Obtain:

☐ Current property acreages of property owned, leased, or used for operational ranges and training

☐ Historical and current real estate maps or GIS files that provide any new information regarding areas used for training (e.g., deed restrictions, aerial photographs, Master Plans).

Pertinent Questions:

1. According to the real estate records, what are the boundaries of the installation and the operational range area?

2. Does the Marine Corps own all the operational range property located within the installation boundary?

   a. If not, which portions are owned by other entities?

3. What rights (e.g., easements, use agreements, leases) does the installation have for operational range / training areas?

   a. Who owns these properties?

   b. Who has management responsibilities?

   c. What are the deed restrictions?

   d. What requirements are associated with the use of the areas (e.g., cleanup, removal, reporting)?

   e. Does the installation have a survey of the leased properties? Is the survey current and accurate?

4. Describe any known deed restrictions associated with the operational ranges.

   a. What area is affected by a deed restriction?

   b. What are the deed restrictions?

5. Describe any additional lands acquired for operational ranges / training areas since the latest Section 366 report.

   a. Identify the location and provide acreage, type, and ownership (e.g., easement, lease).

6. Describe any plans for future land acquisitions for buffer areas or additional training areas.

   a. Location? Acreage? Proposed acquisition date?

7. Compare the latest RCUZ/RAICUZ footprint to any identified information to gather additional data (e.g., ownership, use agreements) on any areas not covered in the questions above.

8. How often does the installation update the INFADS?

9. When an INFADS update occurs, how does the installation ensure that the acreage / range type data updates are correct in the inventory maintained by HQMC/TECOM?

10. If waters of the state are used for training, determine if any written agreements are in place regarding their use. If waters are used for training, indicate types and average amounts of military munitions deployed in each water resource.

11. Where are the areas of greatest concern for encroachment in terms of real property?

    a. Provide a list, including litigation/lawsuits, development, JLUS, zoning, legislation, etc.

3.3.2 Planning/Development

Installation: ______________________________ Date: ____________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: To determine if any development plans are being discussed that may impact the operational ranges.

Documents/Data to Obtain:

☐ Map and plan showing areas to be developed that have the potential to impact the use of the operational ranges (data sources include Installation Master Plan)

Pertinent Questions:

1. What are the future development plans (areas and uses) for the installation?

a. What are the timetables for this development?

b. Where is the location of new development in relation to operational ranges?

2. Does future development impact operational ranges?

3. Is the installation involved in the Buffer Land Initiative?

a. If yes, what area(s) are being considered?

b. Who owns the areas?

c. How will current operational ranges be impacted?

Note: Planning/Development may be a part of Real Estate or Engineering at some installations.

3.3.3 Engineering

Installation: ______________________________ Date: ____________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: To obtain available water supply system information (coordinate with environmental office) and assess locations of planned engineering activities.

Documents/Data to Obtain:

- ☐ Installation production well data (e.g., location, depth, flow rate, well boring data)
- ☐ Sampling results, reports, and analyses of both groundwater supply systems and surface water supply systems (i.e., water intakes / reservoirs)
- ☐ Utility maps (paper, GIS)

Pertinent Questions:

1. What information is available regarding the groundwater associated with the installation and, in particular, the operational range area?

2. Are there water supply wells on the installation?

    a. For what are the wells used (e.g., drinking, irrigation)?

    b. What are the locations of these wells with respect to the operational ranges?

    c. Are the wells being sampled? If yes, for what contaminants? Are you sampling raw or finished water? How often are they sampled? Are they part of a regular sampling program?

3. Are utilities present on/near operational ranges? If so, what and where?

4. Provide engineering specifics (reports, engineering controls) for any identified IRP or UST sites within operational ranges.

5. What other ongoing or planned engineering activities involve operational ranges or areas adjacent to operational ranges?

3.3.4 Facilities Maintenance

Installation: ______________________________ Date: ____________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: To determine how water production wells are maintained and if maintenance activities reveal military munitions.

Documents/Data to Obtain:

☐ Production (i.e., pumping and hydraulic) well data

Pertinent Questions:

1. Describe maintenance activities (e.g., roads, utilities, landscaping / vegetation control) on/near operational ranges.

2. What is the frequency of maintenance in these areas?

3. Have any military munitions been discovered during the described maintenance activities?

4. What maintenance activities are performed on water production wells?

5. Have water production wells been sampled for MC?

3.4 GIS OFFICE

Installation: ______________________________ Date: ___________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: GIS data are integral to the overall understanding of the site and are used in the MC fate and transport modeling for REVA.

Documents/Data to Obtain:

☐ HQMC and installation-specific GIS layers will be requested prior to the site visit. Missing layers will be collected during the site interview (baseline assessment).

Pertinent Questions:

1. How are GIS data created, managed, and updated? Walk us through this process.

2. Confirm which standards are used with previously received information.

3. What layers are available?

   a. Have the range-related data layers been forwarded to TECOM for operational range management? Which, if any, of the general data layers get forwarded to TECOM?

Range-Related Data:	General Data:
☐ Boundaries	☐ Physical
☐ Chemical data	☐ Infrastructure
☐ Targets	☐ Environmental
☐ Firing points	☐ Natural resources
☐ Other	☐ Aerial photographs
	☐ Base maps
	☐ Other

b. Can we obtain these data? What is the process for obtaining data: Ask? Fill out request form? Is approval needed?

Note: GIS Office may be located within the Environmental Office, but it can be a separate office serving the entire installation.

3.5 RANGE MANAGEMENT / RANGE CONTROL

Installation: ______________________________ Date: ____________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: The Range Management / Range Control office is the primary source for data describing range operations at the installation. Range Management / Range Control provides scheduling, expenditure, standard operating procedure (SOPs), management practices, and clearance practices that will enable the estimation of MC loading rates at each operational range.

Documents/Data to Obtain:

- ☐ Range Complex Management Plan (RCMP)
- ☐ Expenditure data (as far back as records are available; are they available electronically; can they identify how accurate the records may be?)
- ☐ Targets and Ranges Information Management System (TRIMS)
- ☐ Range Facility Management Support System (RFMSS)
- ☐ Range SOP
- ☐ Documentation for military munitions that land off range

Pertinent Questions:

1. What year was the range first put into service?

2. Was the range ever out of service for extended periods? If yes, why? What dates?

3. What are your biggest encroachment issues for the operational ranges? (Interviewer: Be sure to check RCMP for encroachment analysis.)

4. Which operational range is getting the most attention regarding encroachment?

5. How do you coordinate with using units? How are schedules set?

6. How are expenditure data tracked? TRIMS, RFMSS, other?

   a. If the expenditure data are tracked by range, can the data be broken down further (e.g., targets, firing point)?

   b. How are expenditure data recorded within the tracking system (DoD Identification Code [DoDIC], etc.)?

   c. What is the process for confirming scheduled use/expenditures with actual use/expenditures?

7. What is the process for collecting foreign military munitions expenditures?

   a. Are they tracked by operational range/target?

   b. Do you have MC or other data on foreign military munitions?

8. How do you track expenditures originating from another location and dropped on your operational range?

9. Have the operational range boundaries (e.g., firing points, direction of fire, SDZs, buffer areas, impact areas) changed over time in comparison to the 366 report?

10. What is the frequency of operational range clearance/maintenance? What is the extent of the clearance?

11. How are records maintained for military munitions that land off range? Where does this information go for follow-up? Who is responsible?

12. Are there documents of known or suspected UXO sites associated with past range activities on operational ranges or the installation (historical use) (besides those identified in the ASR and PRA report)?

13. What records or evidence is there regarding the potential for discarded military munitions (DMM) on the operational range or installation?

14. Identify management practices, such as range clearance and SOP management, employed at the operational ranges.

15. What is the process for selecting, preparing, and placing targets? Could they be a source of contamination?

16. What are the endangered species, special concern species, and cultural and natural resources on or near the operational ranges?

17. Is there a potential for migration of these endangered species, special concern species, or cultural and natural resources onto the operational ranges?

18. What are the procedures for managing T&E species, cultural sites, and natural resources on or near the operational ranges?

19. What restrictions are imposed on operational range utilization by the management of endangered species, special concern species, and cultural and natural resources?

20. Any other historical use?

21. How are records for jettisoned ordnance maintained?

3.6 CPLO/PAO

Installation: ____________________________ Date: ___________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: The CPLO can provide insight into encroachment and compatible land use strategies associated with the communities near the installation and its operational ranges. PAO can provide insight into the relationship with the surrounding community. These offices can also provide a general understanding of the installation's relationship with the outside communities.

Documents/Data to Obtain:

- ☐ Installation Encroachment Control Plan
- ☐ Media relations plan
- ☐ Public relations educational material—military munitions or range related
- ☐ CPLO Campaign Plan

Pertinent Questions:

1. Describe/list both on-base and off-base networks established with state and local agencies, private organizations, and individuals.

2. What is the biggest encroachment challenge facing the installation's ability to support training activities?

3. Who are the specific nongovernmental organizations or groups focusing on the installation and what are their issues?

4. Describe what operational range and training activities have been impacted by community development. Complaints?

5. Identify types and number of complaints logged for training-related activities. How are complaints and inquiries registered/recorded? Resulting action?

6. How interested or active is the public with issues relating to traditional installation restoration sites (do they attend Restoration Advisory Board meetings)?

7. Do you have an internal communication process to report up the chain of command? If so, what is the process and to whom are you reporting?

8. How does the CPLO communicate with neighborhoods? Newsletters? Press releases? Direct distribution to the media?

9. Describe the organizations for which CPLO represents the CG/CO at off-base presentations or public meetings. What is the frequency that CPLO is required/ asked to attend public meetings?

10. Is the CPLO involved in the Buffer Lands Initiative (10 U.S.C. 2684)?

11. What is the process for addressing civilian (e.g., fishermen/hunters) interaction with (retrieving or encountering) military munitions near operational range areas?

12. Ask for suggestions for presenting REVA results externally.

3.7 ATC

Installation: ______________________________ Date: ___________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: To obtain weather data necessary for the fate and transport modeling for REVA.

Documents/Data to Obtain:

- ☐ Weather data (in spreadsheet format rather than reports)
- ☐ Flight plans for missions that drop military munitions, if needed

Pertinent Questions:

1. How do you coordinate with Range Management / Range Control?

2. How frequently do you obtain weather data?

3. Obtain the following (preferably broken out by monthly averages):
   - General weather data
   - Climatological data
   - Precipitation data
   - Wind direction data

Note: The ATC office typically will not have a major role in the overall assessment of operational ranges. Installations may or may not have an ATC office. For installations that do have an ATC, this office is the primary source of weather data. If an installation does not have an ATC office, this information can be obtained by contacting NOAA or via the Internet.

3.8 EOD

Installation: ______________________________ Date: ____________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: The EOD office can provide insight into operational range clearance activities at the installation, as well as incident responses in and around the installation. EOD can provide information such as types of military munitions deployed or recovered at the operational ranges.

Documents/Data to Obtain:

- ☐ Range SOP for EOD Training Range and Subpart X permitted facility, if appropriate
- ☐ Incident response records (emergency response call sheets)
- ☐ Historical operational range maintenance records, if applicable
- ☐ Disposal records for Subpart X permitted facilities—indicate data that are reported through TRI process and hazardous waste annual report
- ☐ Training use records for the EOD Training Range—data submitted for TRI reporting
- ☐ Safety arcs from Subpart X facility and EOD Training Range (do they impact other operational ranges?)

Pertinent Questions:

1. Describe the EOD Training Range present at the installation.

2. How long has the EOD Training Range been operational?

3. Is a Subpart X permitted facility located on the EOD Training Range? If yes, does the permit contain provisions to conduct training at the permitted facility?

4. Have TRI data been submitted for the permitted Subpart X facility (including ground and aviation assets)? Have TRI data been submitted for the EOD Training Range? Describe the process for data submittal.

5. How do you document emergency response calls? Electronically or hard copy? How far back do the records go? Beyond three years?

6. Do you perform any range clearance/maintenance activities (as requested by Range Control)? (Interviewer: Range clearance/maintenance activities are normally not EOD's responsibility. If the answer is yes, ask the following clarifying questions.)

   a. How frequently are range clearance/maintenance activities conducted at each operational range?

   b. How are clearance records maintained?

   c. What are the conditions of the items recovered during range clearance tracked? (Any information on low-orders is helpful. Are there specific military munitions that are prone to low-orders? If a low-order round is spotted, are the military munitions / effected soils cleared as well?)

d. Are maps / Global Positioning System points kept of areas cleared?

e. Who initiates the clearance (e.g., range control, set schedule)?

f. Describe subsurface clearance activities performed.

g. Are there areas specifically not cleared (e.g., water resources, submunition area) and why are these areas excluded?

7. Are there any areas within the boundaries of the operational range or on the installation in which there are potential DMM burial sites (for example, areas where numerous unused military munitions have been recovered over the years)?

8. How are military munitions that land off range handled?

a. Reporting process

b. Record keeping

3.9 SAR

Installation: ____________________________ Date: ___________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Purpose: REVA is assessing the potential impact of lead migration from SARs due to military munitions via the SARAP. The SARAP is a qualitative assessment that determines whether there may be a potential for lead migration at an individual SAR and also enables prioritizing of all the SARs across the Marine Corps for risk of lead migration.

Documents/Data to Obtain:

- ☐ See Data Collection Form (on the following pages)
- ☐ Range SOP
- ☐ List of management practices in place

Pertinent Questions:

1. What is the frequency of range use?

2. What management practices are employed (e.g., bullet traps)?

3. What encroachment issues to the range or SDZs have been identified (e.g., noise)?

4. When was the last time range SOPs were reviewed and updated?

5. What types of military munitions are expended at the range?

6. How are expenditure data tracked (e.g., electronic, hard copy, by DoDIC)? Are these data submitted to EAD/NREA for TRI reporting purposes?

Note: For some installations, the Range Management / Range Control office does not manage operational SARs (including pistol, rifle, machine gun, and skeet/trap ranges). In these instances, the Team will perform a separate interview with the office that manages the SARs.

See Data Extraction/Analysis for determining SARs' conclusions.

REVA Small Arms Range Evaluation

Basic Range Information		
Range Name:	**Period of Use:**	**REVA Date**:
Associated Range Group:		
Range Location:		

Current Range Layout		
Direction of Fire:	**Number of Firing Positions:**	**Length of Firing Line (ft):**
Bullet Trap: ☐Yes ☐No	**Date Installed:**	**Last Recycle Event:**
		Lead Removed (lb):
Back Stop Berm: ☐Yes ☐No	**Date Installed:**	**Last Recycle Event:**
	Construction: ☐Natural ☐Man-Made	
	Berm Groundcover:	**Lead Removed (lb):**
	Berm Condition:	
	Distance from Berm to Installation Boundary (ft):	
Target Material:		
Potential for Lead Contamination in Target Material: ☐Yes ☐No **Where:**		

Current Range Operations	
Range Management Entity:	
Range Mission:	
Range Management Comments:	
SOPs: ☐Yes ☐No	**SOP Date:**
Authorized Weapons: ☐Pistol ☐Shotgun ☐Rifle ☐Crew-Served Weapons	**Authorized Military Munitions:** ☐.22 cal ☐.30 cal ☐.38 cal ☐.45 cal ☐.50 Cal ☐5.56 mm ☐7.62 mm ☐9 mm ☐12-gauge
Duration of Current Use:	**Frequency of Use:** ☐Heavy (daily) ☐Light (monthly)
Range Use Restrictions: ☐Yes ☐No	**Restriction Type:** ☐Noise Levels ☐Operating Hours
Road Traffic Interference: ☐Yes ☐No	**Maritime Traffic Interference:** ☐Yes ☐No
Aerial Traffic Interference: ☐Yes ☐No	**Wildlife Interference:** ☐Yes ☐No
Describe Interference:	
Describe Interference Mitigation Protocols:	
Surface Danger Zone Issues: ☐Yes ☐No	**If yes, explain:**

Ricochet Hazards: ☐Yes ☐No	**If yes, explain:**
Are or have "green" military munitions (i.e., tungsten rounds) ever been used on this range? ☐Yes ☐No **If yes, when, for how long, and approximately how many?**	

Historical Range Operations	
Historical Range Name:	
Range Type:	
Period of Historical Use:	**Duration of Historical Use (yrs):**
Military Munitions: ☐.22 cal ☐.30 cal ☐.38 cal ☐.45 cal ☐.50 cal ☐5.56 mm ☐7.62 mm ☐9 mm ☐12-gauge	
Did historical military munitions use potentially deposit UXO within this SAR? ☐Yes ☐No	
Has a range clearance of this historical use area been performed? ☐Yes ☐No **If yes, describe clearance results (dates, areas, and significant findings):**	

Amount of Lead Potentially Deposited			
Military Munitions Expenditures			
DoDIC	**Nomenclature**	**Annual Average Quantity Used (each)**	**Amount of Lead Potentially Deposited Annually (lb)**
	Small Arms Totals:		
• **Average Quantity of Military Munitions Expenditures Based On:**			
MC Loading Area Description:			
MC Loading Area Size (m^2):			

MC Loading Rates (kg/m^2)				
Period A	**Period B**	**Period C**	**Period D**	**Period E**

Environmental Characteristics	
Range Environmental Setting:	
Range Management Practices: ☐Seeding **Date Last Performed:** ☐Fencing **Date Last Performed:**	

☐Riprap	**Date Last Performed:**
☐Excavating	**Date Last Performed:**
☐Grading	**Date Last Performed:**
☐Soil Liner	**Date Last Performed:**
☐Drainage Systems	**Date Last Performed:**
☐Lime	**Date Last Performed:**
☐Mining/Sifting	**Date Last Performed:**
☐Limited Training	**Date Last Performed:**
☐Pick Up Brass	**Date Last Performed:**
☐Other: NA	**Date Last Performed:**
☐Reconstruction	**Date Performed:**

Environmental Characteristics		
Annual Precipitation (in):	**Subject to Major Storms:** ☐Yes ☐No	**Tidal Influence:** ☐Yes ☐No
	Soil Type:	**Soil pH:**

Surface Water	
Direction of Surface Water Flow on Range:	
Direction of Surface Water Flow from Backstop Berm:	
Terrain of Land Near Berm:	
Drainage System: ☐Natural ☐Ditches/Culverts	**Captured Runoff:** ☐Yes ☐No

Groundwater	
Depth to Groundwater (ft):	**Distance to Nearest Drinking Water Well (ft):**
	Location of Nearest Drinking Water Well:

Potential Receptors
Human: ☐Range Users ☐Industrial ☐Recreational ☐Residential
Ecological: ☐State-Listed ☐Candidate ☐Threatened ☐Endangered ☐Other **Identify "Other" Receptor:**
Wetlands: ☐Non-Jurisdictional ☐Jurisdictional ☐Tidal Influence on Wetlands
Surface Water Bodies: ☐Creeks/Streams ☐Ponds ☐Rivers ☐Wetlands
Distance to Nearest Potential Receptor: ☐Human (0 ft) ☐Ecological (0 ft) ☐Wetlands (0 ft) ☐Surface Water (50 ft)

Surrounding Land Use
☐Operational Range ☐Industrial ☐Commercial ☐Agricultural ☐Recreational ☐Residential

Environmental Activities	
Sampling Event Description:	**Reasoning:**
Sampling Date(s):	**Sampling Location:**
Media: ☐Surface Soil ☐Subsurface Soil ☐Surface Water ☐Groundwater ☐Drinking Water ☐Ecological **Identify Ecological Samples:**	
Summary of Results:	

Sampling Event Description:	**Reasoning:**
Sampling Date(s):	**Sampling Location:**
Media: ☐Surface Soil ☐Subsurface Soil ☐Surface Water ☐Groundwater ☐Drinking Water ☐Ecological **Identify Ecological Samples:**	
Summary of Results:	

Summary					
Range Characteristic	**MC Migration Factor**	**Effect on MC Migration**		**Factor Evaluation Guidelines**	
		+	-	**Positive**	**Negative**
Current Range Layout	Distance to Installation Boundary	☐	☐	> SDZ	< SDZ (i.e., SDZ extends beyond installation boundary)
	General Condition of Berm	☐	☐	Consistent elevation and vegetation	Rutted and/or deteriorating
Current Range Operations	Frequency of Use	☐	☐	Sporadic (i.e., monthly)	Regular (i.e., daily)
Historical Range Operations	Legacy MC Source Areas	☐	☐	Not present or remediated	Present
Environmental Characteristics	Range Management Practices	☐	☐	Timely and/or effective	Nonexistent or existing but not effective
	Erosion Control Measures	☐	☐	Not needed, existing, and/or effective	Nonexistent or existing but not effective
	Weather	☐	☐	Frequent major storms or flooding (e.g., hurricanes)	High average annual precipitation rates
	Soil Type	☐	☐	Clay	Sand
	Soil pH	☐	☐	pH $\geq$ 6	pH < 6
	Soil Moisture	☐	☐	Wet, anaerobic conditions	Dry, aerobic conditions
	Water Salinity	☐	☐	Low (≤ 6%)	High (> 6%)
	Berm Terrain	☐	☐	Terraced, firmly packed	Graded, loose material
	Terrain of Land Adjacent to Berm	☐	☐	Flat	Hilly
	Berm Drainage	☐	☐	Directed/captured	Natural
	Groundcover	☐	☐	Vegetated	Barren or spotty
	Area Capturing Runoff or Drainage	☐	☐	Managed storm water, dry, or tidally influenced	Wetlands
	Depth to Groundwater	☐	☐	Deep	Shallow
	Location of Nearest Drinking Water Well	☐	☐	MC loading area outside of well drawdown area	MC loading area within well drawdown area
Surrounding Land Use	Surrounding Land Use	☐	☐	Operational	Other than operational range and/or nonrange area
Environmental Activities	Sampling Results	☐	☐	MC not present in sampled media	MC present in sampled media

3.10 OTHER OFFICES

If sufficient time remains during the site visit, additional offices on the installation should be visited to obtain ancillary data that may provide additional information to address potential/identified data gaps. These offices may include the Base Historian, Library, and Explosive Safety Office. These offices should be visited with specific data requirements in mind in order to minimize time and expenses associated with "historical" research within these offices.

3.10.1 Library

Installation: ______________________________ Date: ____________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Documents/Data to Obtain:

- ☐ Historical and current aerial photographs, maps of operational ranges, or historical ranges (supplement the ASR)
- ☐ Articles/stories pertaining to military munitions and/or training
- ☐ Information on the surrounding community

3.10.2 Base Historian

Installation: ______________________________ Date: ____________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Documents/Data to Obtain:

- ☐ Command chronology
- ☐ Historical data (e.g., maps, photographs, documents) associated with the installation and/or operational ranges (supplemental to ASR data)

Pertinent Questions:

1. Provide history of installation and/or operational range use.

2. What units / operating forces historically have used the operational range(s)?

3. How has the operational tempo at the installation changed over time? Number of troops, flights?

4. What were the military munitions classes used by each user unit?

3.10.3 Explosive Safety Office

Installation: ____________________________ Date: ___________

Name, Title of Interviewer: ____

Name, Title of Interviewee: ____

Documents/Data to obtain:

- ☐ Reports that provide supporting range information

Pertinent Questions:

1. What management practices are implemented at the operational ranges to ensure safe training?

2. How are the firing fans, safety arcs, and SDZs established or changed on operational ranges?

3. How are incident reports tracked/managed?

This page left intentionally blank

4.0 DATA EXTRACTION

Specific information contained within documents and information obtained during the data collection process were extracted to perform an adequate and effective assessment of operational ranges. The data elements that required extraction for the assessment include operational range boundaries, military munitions expenditures, and fate and transport modeling parameters. In order to assist data extraction, the DCM (Section 3) contained color-coding highlighting specific questions/documents that pertain directly to one or more of these required elements. Portions of the DCM that did not contain color-coding were supplemental information that may have been used to confirm and/or enhance knowledge for completion of the assessment.

4.1 OPERATIONAL RANGE BOUNDARY

In order to determine whether a release or threat of a release of MC from an operational range existed, the real property used for operational ranges had to be understood in terms of boundaries and ownership. Range boundaries had to be confirmed to determine an appropriate and accurate picture of the operational range area. This information was obtained from Section 3.3.1 Real Estate and Section 3.5 Range Management / Range Control.

4.2 DMM

Based on interviews with Range Management / Range Control and/or EOD, if DMM or munitions burial sites were identified to potentially exist, the DMM were to be investigated as necessary to confirm their actual existence. Investigation may have included activities such as identifying potential known coordinates, researching the ASR/PRA, interviewing the person with knowledge of the area, and locating the DMM with a magnetometer. If DMM were confirmed on an operational range, the appropriate installation POC immediately notified HQMC to determine appropriate actions to address the area.

4.3 MILITARY MUNITIONS EXPENDITURES

The REVA fate and transport model requires an estimate of the MC loading of each indicator MC. Information obtained in the DCM to assist in determining the MC loading was color-coded red.

The indicator MC fate and transport screening-level modeling analyses required estimation of the amount of MC deposited on operational ranges over time in order to determine if there was a potential for a release or substantial threat of a release of MC. Within REVA, the amount of MC deposited on operational ranges over time is referred to as MC loading. Operational range usage, name, and boundaries have changed over time; therefore, an analysis of range history had to be performed to map all potential MC loading areas and to calculate the MC loading. Operational ranges may have been subdivided into one or more MC loading areas if military munitions expenditure data were available to segregate MC loads into discrete areas across the operational range representing locations where the majority of the MC had been deposited. MC loading areas may include current, as well as historical, use areas within the operational ranges, such as bomb targets, artillery targets, and training and maneuver areas. The MC loading for the operational ranges was estimated separately for each MC loading area within that operational range and for each indicator MC. For the purposes of REVA, the MC loading estimates were considered as average concentrations deposited annually in a defined MC loading area within the operational range for the duration of the period that the operational range activities generating the MC loading were conducted. Typical published dud and low-order detonation rates for ammunition items were used.

The initial REVA for each installation established a baseline accounting for operational range activities since the range's first use. During the REVA baseline assessment, MC loading estimates were calculated based upon the data available at the time of the assessment. The fate and transport screening-level models assumed an average MC loading rate for the historical use years based upon the average for the most recent years to project if a release or potential release may occur in the future. The process used to calculate the baseline MC loading rates is described in Section 4.3.3 Estimating MC Loading.

The following operational range–specific information regarding military munitions types was required to calculate the potential MC loading for each operational range:

- Military munitions expenditure data (type and quantity)
- Quantity of indicator MC in each type of military munitions expended
- Estimates of dud and low-order detonations rates for each military munition in the installation operational expenditure data
- Estimated amount of MC remaining after each low-order detonation and estimation of its distribution on the operational range
- Frequency of military munitions clearance activities conducted at the site (i.e., potential to decrease the MC loading rate)

4.3.1 Indicator MC

Numerous studies on the frequency of occurrence of specific MC in soil and groundwater have shown that trinitrotoluene (TNT) and/or cyclomethylene trinitramine / Royal Demolition Explosive (RDX) have been detected in a high percentage of analyzed samples. Studies have also shown that RDX, cyclotetramethylene tetranitramine (HMX), and ammonium perchlorate (perchlorate) are mobile within the environment and have the highest potential to migrate off range. TNT, RDX, HMX, and perchlorate can persist in the environment for long periods of time. In addition, lead is a commonly identified metal associated with small arms military munitions. For these reasons, the baseline assessment investigated TNT, RDX, HMX, perchlorate, and lead. These constituents were considered indicator compounds. The potential for lead releases from SARs was assessed qualitatively, as described in Section 7.2.

An analysis was also performed based upon the Marine Corps noncombat expenditure allowance (NCEA) data to determine the average amounts of MC expended per year across the Marine Corps (training allowance allocations). Along with their potential environmental impact characteristics, the following indicator MC were determined to be the largest amount (by pound) used across the Marine Corps. The identified indicator MC are shown below along with their determined amounts allocated across the Marine Corps.

- TNT 2,356,715 pounds (lb)
- RDX 2,162,419 lb
- HMX 817 lb
- Perchlorate 33,145 lb
- Lead 1,090,967 lb

Due to its environmental chemical properties and the relatively low amount used throughout the Marine Corps, pentaerythrioletranitrate (PETN) was not included as an indicator MC.

MC associated with small arms ammunition commonly used at operational ranges include lead, antimony, copper, and zinc. REVA focuses on lead as the MC indicator for SARs because lead is the most prevalent (by weight) potentially hazardous constituent associated with small arms ammunition, as noted above. No specific quantitative conclusions can be made regarding the fate and transport of lead since it is unlike any other MC; however, like many contaminants, lead has the potential to migrate in surface water pathways and be carried off range. Lead is geochemically specific regarding its mobility in the environment. Site-specific conditions (i.e., geochemical properties) must be known in order to quantitatively assess lead migration. Site-specific geochemical properties are only identified via sampling and cannot be observed physically. Without site-specific physical and chemical characterization, lead cannot be modeled effectively using fate and transport modeling like the other indicator MC in REVA. Many studies have indicated that metallic lead (such as recently fired, unweathered bullets and shot) generally has low chemical reactivity and low solubility in water and is relatively inactive in the environment under most ambient or everyday conditions. However, a portion of lead deposited on a range may become environmentally active if the right combination of conditions exists.

4.3.2 MC Assumptions

At the time of the baseline assessments, military munitions expenditure data had only recently begun to be recorded, so assumptions were made regarding historical uses and quantities to determine MC loading. Assumptions were made throughout the MC loading analysis process pertaining to the spatial distribution of the MC on the site. In areas that did not have fixed or known targets (such as training and maneuver areas, where military munitions such as pyrotechnics have been used sporadically throughout the area) the MC loading was assumed to be evenly distributed (i.e., homogenous) across the area. In other cases, the MC loading was assumed to be concentrated at discrete points within the individual target areas. MC loading maps were developed to depict the areas where the MC loading was applied.

In order to estimate MC loading for operational ranges[1], the following assumptions were used in the REVA baseline assessment process for explosives and perchlorate:

- Only the main fillers and propellant components (REVA indicator MC) were included in the estimates. The amount of MC located in fuzes, boosters, and other components was not considered significant enough, by comparison, to impact the MC loading amounts.
- MC loading rates were estimated only for the MC on the indicator list.
- All REVA indicator MC were considered 100% pure and, therefore, more readily transported in the environment.
- One percent of residual REVA indicator MC was considered reactive within the environment.
- Dud and low-order detonation rate estimates were used from the *Report of Findings for Study of Ammunition Dud and Low-order Detonation Rates* (U.S. Army Defense Ammunition Center, 2000).
- One hundred percent of all duds resulted in exposed MC.
- For low-order detonations, it was assumed that 50% of the total MC per item was consumed (expert opinion based on U.S. Army Environmental Command [AEC] reports by Dauphin and Doyle, 2000 and 2001).
- Training factors described in Section 4.3.4 were applied to the specified periods, and the MC loading rates were adjusted accordingly.

[1] MC loading was calculated for historical use areas within operational ranges if they had not been cleared, as continued MC loading results from potential historical dud loads.

4.3.3 Estimating MC Loading

There are three main sources that contribute to the MC mass loading on an operational range:

- Mass of MC associated with low-order detonations (Figure 4.3-1)
- Dispersed MC mass at the soil surface associated with high-order detonations (Figure 4.3-2) (assumed to be uniformly mixed within the top soil)
- Leachate from corroded UXO

Figure 4.3-1: Low-order detonation point source
Source: U.S. Army Engineer Research and Development Center/Cold Regions Research and Engineering Laboratory, 2005

Figure 4.3-2: High-order detonation
Source: U.S. Air Force, Edwards Air Force Base

The MC loading was estimated based on mass-loading principles (e.g., military munitions expenditure data, dud and low-order detonation rates). Studies have shown that MC are deposited on the operational range through low- and high-order detonations and may leach from corroded UXO. These processes are presented in the equation below:

Total MC loading = MC (low-order) + MC (high-order) + MC (UXO)

Notes:
1) MC (low-order) is the amount of MC deposited as a result of low-order detonations.
2) MC (high-order) is the amount of MC deposited as a result of high-order detonations.
3) MC (UXO) is the amount of MC deposited as a result of leaching from corroded UXO.

Studies throughout DoD have shown that the MC remaining from high-order detonations are much less significant than the amount of MC deposited on an operational range from low-order detonations. Other studies conducted by the Army show that it typically takes a significant amount of time for UXO to corrode. Although MC remaining from low-order detonation are the most significant contributor to MC loading, REVA accounts for MC attributed to all three of these potential sources.

MC loading estimates for low-order and high-order detonations and UXO for the MC loading areas associated with each operational range are estimated using the equations below:

MC (low-order) = (Number of military munitions expended) x (low-order detonation rate) x (amount of residual remaining from a low-order detonation) x (% available to environment)

MC (high-order) = (Number of military munitions expended) x (high-order detonation rate) x (amount of residual remaining from a high-order detonation) x (% available to environment)

MC (UXO) = (Number of military munitions expended) x (dud rate) x (amount of residual exposed as a result of damage to UXO casings)

Dud rate and low-order detonation rate data for REVA were estimated based upon *Report of Finding for Study of Ammunition Dud and Low Order Detonation Rates* (U.S. Army Technical Center for Explosives Safety, 2000). Dud and low-order detonation rates for military munitions in this report are tracked, reported, and made available according to military munitions DoDIC. For the DoDICs where dud or low-order detonation rates were not available, the default values of 3.45% (dud rate) and 0.028% (low-order detonation rate) were used. For the purposes of the baseline REVA, it was assumed that the amounts of residual explosives remaining after a low-order detonation and a high-order detonation were 50% and 0.1%, respectively.

The primary source providing the types and amounts of energetic fillers associated with the military munitions known or suspected to have been used at the operational ranges is the Defense Ammunition Center's Munitions Items Disposition Action System (MIDAS)[2] Web site (https://midas.dac.army.mil/). In addition to MIDAS, other sources used for MC data include the ORDDATA II software (Enhanced International Deminer's Guide to UXO Identification, Recovery and Disposal; Version 1.0, 1999) and various ordnance technical manuals. In cases where specific military munitions use data were unavailable, the military munitions types selected during the baseline assessment were based upon common military munitions used during the active time periods of the operational range. Perchlorate data were obtained from an analysis of perchlorate-containing military munitions, which could be obtained from various technical manuals or other electronic database systems, such as MIDAS.

4.3.4 Estimating Military Munitions Expenditures Loading

Installations are to maintain expenditure data for their operational ranges in accordance with DoDD 4715.11. The use of documented electronic expenditure data is preferred in REVA. However, there were many cases (including most historical use areas) where expenditure data had not been maintained. For these cases, during the baseline assessment, the amount of military munitions expended for each MC loading area had to be estimated. The time periods during which the operational range areas had been in use were often greater than the amount of time that expenditure data had been kept and

[2] Data were retrieved from MIDAS by performing searches for the MC, which produced a list of military munitions and their respective amounts of MC. The list of military munitions was then evaluated, as more than one matching National Stock Number was often listed, and the highest and lowest MC quantities were captured and averaged for REVA MC loading estimate calculations.

maintained; therefore, specific assumptions were necessary to determine MC loading for each of the MC loading areas for baseline MC loading. When actual expenditure data were not available, two estimating processes were used as applicable: 1) training analysis method and 2) training allowance extrapolation method, as detailed below.

4.3.4.1 Training Analysis Method

The training analysis method involves reviewing the types of training conducted on the operational range, the weapon platforms used, the military munitions associated with the specific weapon platforms, and the frequency of training activities conducted at the operational range. For example, there may be a SAR with 20 firing positions that have been in use for 10 years. Estimating the number of personnel trained and the number of military munitions expended per training session, as well as the number of days on average the range was operational (i.e., frequency), the total military munitions expended on the operational range can be estimated. Using the same example of a SAR with 20 firing positions being used for pistol qualification training, a reasonable conservative assumption can be made on the number of rounds on average that each Marine fires during training. The frequency of training or range use is then estimated to arrive at the total number of rounds potentially expended over time. The assumptions used in this type of analysis were based upon data collected by the REVA Team, including interviews with Range Control personnel and expert judgment based upon knowledge of Marine Corps training requirements. In cases where this type of analysis was used, the specific assumptions were documented in the installation's REVA report.

4.3.4.2 Training Allowance Extrapolation Method

The training allowance extrapolation method is used only when no other data are available. This method involves using the NCEA data for the Marine Corps that are available to the REVA Team. NCEA data are available for FY03 through FY12 for military munitions allocated for training across the Marine Corps. NCEA data are not installation-specific, but rather give the amounts allocated for training by the entire Marine Corps (by military munitions type). The training allowance extrapolation method takes a percentage of the military munitions allocated for training across the Marine Corps (i.e., NCEA data) and applies the percentage to a specific installation. In order to estimate the amount used on a particular operational range, the specific types of military munitions used on the operational range were taken from data sources such as the ASR and PRA report. Then an estimate was made on the percentage of the overall NCEA values that were used on that operational range.

For example, it may be assumed that 5% of the small arms NCEA quantities were used at a SAR at an installation. The percentage allocations were based upon a general knowledge of the operational ranges across the Marine Corps. Because the NCEA data are a projection of the amount of military munitions that will be used for training across the Marine Corps and do not account for contingencies (e.g., war reserve), the training allowance extrapolation method was used only when no other data were available. If some data exist regarding actual military munitions used at the operational range, the training analysis method was used.

4.3.5 REVA MC Loading Rate Calculator

The REVA MC Loading Rate Calculator (Calculator) was developed during the baseline assessments to provide an automated method to calculate the overall MC loading for an MC loading area based upon the military munitions quantification methods discussed in Sections 4.3.2 and 4.3.3. The Calculator uses a baseline annual expenditure rate that is then applied to each year the operational range is known or suspected to have been operational to estimate the MC loading for the MC loading area associated with that operational range.

The Calculator also applies values for the data discussed in Section 4.3.3 (dud rate, low-order detonation rate, high-order detonation rate, residual amount of MC remaining) in kilograms (kg) and area in square meters (m^2) so that the MC loading concentration is presented in the units needed for the fate and transport screening-level modeling analyses (kg/m^2).

4.3.5.1 Microsoft Office Excel®-Based Calculators

The originally developed Microsoft Office Excel®-based Calculator has nine worksheets (once completed). The first worksheet (Summary) presents a summary of the MC loading rate worksheets. The second through fifth worksheets document the types and quantities of military munitions expended within each MC loading area that were used to estimate the MC loading rates (for HMX, RDX, TNT, and perchlorate, respectively). The MC loading rates were determined by referencing the military munitions and training analysis worksheets for MC and variations in the levels of training over time. The MC loading rates account for surface deposition of MC from duds and low-order detonations, as well as ubiquitous distribution of the residual MC resulting from high-order detonations (residual default value estimated at 0.1%) throughout the upper 6 inches of soil.

The sixth worksheet is the lead worksheet, which documents the types and quantities of military munitions expended on SARs only. SARs were reviewed qualitatively during the baseline assessment to identify current and past practices affecting potential lead migration, including the SAR overall design, storm water drainage, operation and maintenance, and management of expended military munitions.

The seventh worksheet is the military munitions worksheet, which is referenced by each MC loading rate worksheet (worksheets 2–5) to obtain the appropriate MC data for the actual military munitions expended on the operational range associated with the MC loading area being modeled. These MC data primarily are retrieved from the MIDAS database; however, additional resources are used when MC data are not available for a particular military munitions item. This worksheet also provides the dud rate associated with each military munitions item that is referenced by the MC loading rate worksheets.

The eighth worksheet, used for informational purpose only, lists all items (by DoDIC) that do not contain MC associated with dud or low-order detonations, such as blank, inert, or practice military munitions that do not contain MC. These items were identified but were not associated with the modeling investigation during the baseline REVA since they do not contain indicator MC.

The ninth worksheet is the training analysis worksheet, which accounts for the fluctuations in training associated with pre- and postwar periods. This spreadsheet indicates five distinct periods (A through E) during which the training levels were adjusted to account for the effects of war on training. The MC loading rate worksheets reference these periods to account for the appropriate increases or decreases in training from the established baseline year and apply them to the operational range associated with the MC loading area being modeled.

The Excel®-based REVA MC Loading Calculator details and its development are contained in Appendix D.

4.3.5.2 Microsoft Office Access®-Based Calculator

The originally developed Excel®-based Calculator was used to develop a Microsoft Office Access®-based Calculator to ensure accuracy and eliminate user error when calculating MC loading. The same assumptions and principles described above for each spreadsheet of the Calculator are applicable to the Access® version (along with some programming to eliminate some of the data entry). The Access® Calculator calculates the same concentration (kg/m^2) of MC per loading area across the designated time periods while accounting for the changes in training time periods. This Calculator can be used to calculate MC loadings in the future. The details of this Calculator are also contained in Appendix D.

4.3.6 MC Loading Area Determination

The area impacted by the estimated MC loading was defined with the approach outlined in order to accurately run and analyze the fate and transport screening-level models. Since these areas typically were not representative of the range boundary, range fan, or SDZ, they were referenced within REVA as MC loading areas. These MC loading areas are the locations where the MC loading rates were applied to determine if there was a release or threat of a release of MC from the operational range. It was assumed that MC were distributed equally throughout the defined MC loading area.

The size, shape, and geographic location were considered when defining an MC loading area. It was generally presumed that greater MC concentrations exist within the immediate impact/target area of an operational range, with concentrations decreasing as distance from these areas increases. Therefore, the MC loading area was an estimate of where the majority of the MC was believed to be deposited.

The size of an MC loading area had a direct effect on the modeling results. If an MC loading area was defined as too large of an area, then the MC loading rate was diluted; if it was defined as too small of an area, then the MC loading was concentrated. Inappropriate sizes could lead to improper model results; therefore, it was important to use all of the information available to define an MC loading area.

The shape of an MC loading area may or may not reflect the designated target area. For example, historical bombing targets that were marked on the ground as a circle may have enlarged MC loading areas to account for inaccuracies in early aviation bombing techniques. In addition, MC loading areas may be modified for direction of approach. For example, a bombing target that has had an east-to-west approach since its inception may have a football-shaped MC loading area to account for early and late target engagements (long and short shots).

Operational training and maneuver areas normally encompass all lands up to the installation boundary; however, normal maneuvers do not extend entirely to the boundary. In order to accurately account for this, a 100-foot buffer was added inward on the entire installation boundary area.

The location of an MC loading area weighed heavily toward MC concentrations that exist within the immediate impact/target area of an operational range (historical use and/or current), with concentrations decreasing as distance from these areas increases. Range boundaries, range fans, and SDZs are large areas establishing the required safety parameters for the weapons systems being employed and for the design of a particular range. These established safety parameters, which may be accompanied by additional buffer lands between the defined operational range and the boundary of the entire operational area, may have encompassed sensitive areas (e.g., wetlands, streams) that were not affected by training activities or the associated MC. There were instances where areas were excluded from the modeling. The rationale for excluding these areas was documented, showing no military munitions have been used or disposed of at these areas.

Complex operational range facilities may have multiple MC loading areas; however, depending on changes in range use and direction of fire over time, it may have been more appropriate to define a larger collective MC loading area (see example in Figure 4.3-3). In such instances, it was determined that a worst-case scenario within the larger MC loading area was more appropriate to model. Therefore, additional assumptions were required, such as assuming that a higher percentage of the MC loading is being deposited into a smaller region of the MC loading area that is near the operational range or installation boundary and in the direction of surface water and/or groundwater flow.

Sources of information to assist in defining MC loading areas included GIS data, aerial photography (historical and current), historical maps, ASRs, PRA reports, and input from range controllers as well as training and operations personnel. Professional judgment based on historical and current operational uses of the ranges was used to validate the assumptions compiled from various sources.

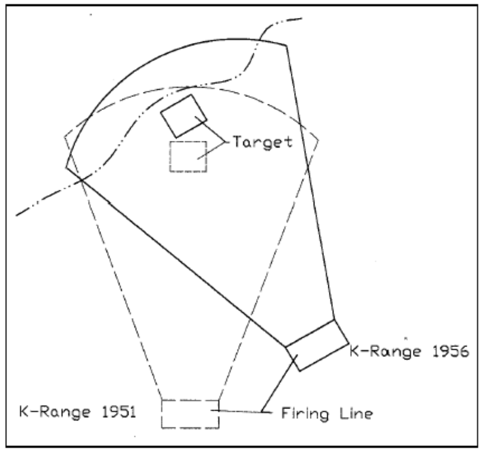


Figure 4.3-3: Range orientation shifts

4.3.7 Time-Dependent MC Loading

Once the MC mass loading rate was estimated, it was used along with the dissolution rate and infiltration rate in the computer-based fate and transport screening-level models. Depending upon the environmental conditions at the site (such as topography, soil type, and land use) and chemical properties of the MC, all MC deposited on the operational range may not have infiltrated into the subsurface. Some MC may have eroded with soil particles, washed away in rain runoff, or evaporated. The remaining MC are factored into subsequent model runs (next iteration). Figure 4.3-4 shows a schematic of the model inputs, the calculation, and outputs over time.

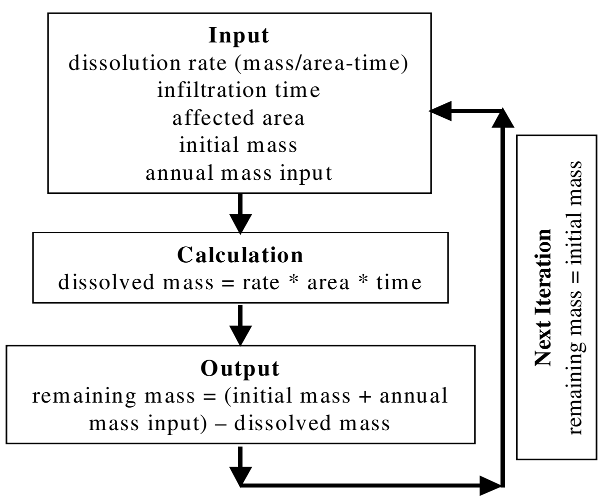


Figure 4.3-4: Determination of dissolved MC mass

4.4 FATE AND TRANSPORT MODELING DATA

Specific environmental characteristic data were used to conduct both groundwater and surface water screening-level fate and transport modeling during the baseline assessments. The information was as specific as possible to the MC loading area that was being modeled. Each MC loading area was modeled individually and then as part of the model for the whole operational range, as applicable.

The following environmental characteristic information was needed for fate and transport screening-level modeling and was color-coded blue within the DCM (Section 3):

- Shallow (unconfined) aquifer data
    - Depth to groundwater table
    - Thickness of aquifer
    - Depth to and thickness of any aquitards (clay layers / confining layers)
    - Groundwater flow direction and rate
- Deep (confined) aquifer data
    - Depth to groundwater table
    - Thickness of aquifer
    - Depth to and thickness of any aquitards (clay layers / confining layers)
    - Groundwater flow direction and rate
    - Piezometric head (elevation)
    - Piezometric surface/gradient
- Well data for ***all*** wells that may be impacted by range operations
    - Well location
    - Well use (drinking, irrigation)
    - Depth
    - Flow rate
    - Stratigraphy
- Soil data
    - Type of surficial (top 6 inches to 1-foot depth) soils (sandy, clayey, etc.)
    - Type of subsurface (below 1-foot depth) soils
- Land cover/use

  - Vegetation type
- Local topography in 1-foot contours (preferably)
- Precipitation
  - Total annual (and/or seasonal, where applicable) precipitation together with the estimated infiltration rate
  - Total annual (and/or seasonal, where applicable) contaminant flux from the soil surface for each MC (to be determined by calculation)
- Surface water:
  - Nature of surficial streams within and around the operational range (permanent, intermittent, some idea about the flows)
  - Drainage area and discharge patterns from the operational ranges into surface waters
- Receptors
  - On site
  - Off site

4.5 POTENTIAL AIR PATHWAY

There are two potential routes of off-range migration of MC via the air pathway. The first is the release of MC directly to the air during functioning (e.g., detonation) of munitions items. These MC potentially migrate off range via wind currents. The second is off-range migration of MC particles, or soil particles with MC sorbed to them, by wind entrainment.

4.5.1 Air Emissions from Functioning Munitions

Functioning munitions include both firing and detonation. Emissions from functioning munitions have been evaluated using several different approaches. These include an evaluation of potential inhalation risks, assessments of ongoing open burning / open detonation (OB/OD) facilities, and a review of air quality dispersion modeling.

<u>Emissions Program Evaluation of Inhalation Risks:</u> AEC and the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) Environmental Health Risk

Assessment Program have developed a process to evaluate potential inhalation risks from munitions' air emissions to off-site residents living near Army training facilities.

Potential inhalation risks from munitions' air emissions for over 180 chemicals were determined using real-world emission factor data obtained from tactically test firing point, smoke/pyrotechnics, and exploding ordnance munition items. Conservative estimates were used for modeling. Exposures were based on a hypothetical residential population most likely to be affected consisting of older adults and children living 100 meters away, directly downwind under worst-case meteorological conditions, with the wind constantly blowing toward the exposed population 350 days a year.

Health Risk Assessments indicate there is minimal, if any, potential health risk to off-site residents living near these training facilities.

Since these studies were not modeled after any one existing training facility, conservative model input data were used so that results are generic enough to be applicable to most facilities that use these military munitions items.

Since the Marine Corps uses similar types of military munitions and has similar range uses, the conclusions of these studies can be applied to Marine Corps operational ranges also.

<u>Assessment of OB/OD Activities:</u> Information on emissions directly from munitions functioning can also be found in Agency for Toxic Substances and Disease Registry (ATSDR) assessments of air emissions of MC from OB/OD sites. An evaluation of these reports indicates that it is unlikely that emissions from functioning munitions represent a complete exposure pathway. In a report documenting the Health Consultation for the air pathway at Sierra Army Depot (SIAD), California (the largest munitions OB/OD treatment operation in the DoD), ATSDR concluded that:

> Even for the downwind directions, these emissions disperse considerably over the distance that separates SIAD from locations where people live. ATSDR reviewed findings from several modeling studies and an extensive air sampling study, all of which indicate that residents in the

> area have not been exposed to levels of air pollution that are associated with adverse cancer or non-cancer health effects. (Brown and Root Environmental, 1996)

The ATSDR Health Consultation report includes estimates for annual average concentrations of chemicals evaluated in SIAD's human health risk assessment. The estimated annual average air concentrations for the 12 chemicals that have health-based screening values were all more than 100 times lower than the most conservative comparison value. The results led ATSDR to conclude that "actual exposure concentrations of explosives, propellants, and fillers are not greater than levels of health concern" (Brown and Root Environmental, 1996).

The ATSDR also evaluated the air exposure pathway at a Navy operational range in Vieques, Puerto Rico. The assessment concluded that:

> Most of the contaminants released to the air during past military training exercises involving live bombs were dispersed to extremely low concentrations over the 7.9 miles that separate the center of the live impact area from the nearest residential areas of Vieques. ATSDR's best estimates of ambient air concentrations suggest that past exposures during the live bombing exercises were at levels below those associated with adverse health effects. (Brown and Root Environmental, 1996)

Review of Air Quality and Dispersion Modeling: Review of air quality and dispersion modeling documents for the Utah Test and Training Range indicates that large-scale detonations, like the Utah Test and Training Range Thermal Treatment Unit large rocket motor detonations, displace tons of soil and create fine particle plumes that may travel tens of kilometers. In general, sampling for air quality parameters has found levels that are consistently below exposure thresholds for population exposures directly following detonations.

Conclusion: On the basis of air emissions data from munitions testing, OB/OD sampling, and dispersion modeling, health risk to off-range receptors from air-transported MC is unlikely. Therefore, no detailed assessment was performed.

4.5.2 Re-entrainment of Dust Potentially Containing MC

Soil Sampling Investigations: The second potential method for off-range migration of MC via the air pathway is the transport of MC particles, or MC sorbed to soil particles, carried by wind. This migration pathway assumes a readily transportable source of MC in the top inch of soil and/or sorbtion of those constituents to soil particles. Extensive sampling of soils in Army impact areas has shown that explosives residues tend to be localized in highly distributed point sources associated with low-order detonations and the vast majority of impact areas show very little or no detectable explosives residues. While localized point sources could, in some instances, provide a source for off-range migration of MC in water, these localized sources are very unlikely to be mobile in the air pathway. AEC/USACHPPM soil sample results collected in a random or systematic random fashion from different Army artillery impact areas show soil concentrations of explosives residues and metals to be well below levels that would pose a health risk to on-range human receptors. U.S. Army Corps of Engineers studies of explosives residues from detonation of Army munitions show that high-order detonations from live-fire training do not appear to widely distribute large amounts of explosives residues on Army training ranges (U.S. Army Corps of Engineers, 2001).

Since the Marine Corps uses similar types of military munitions and has similar range uses, the conclusions of these studies can be applied to Marine Corps operational ranges also.

Conclusion: On the basis of existing data and studies, air transport of MC from typical training at levels that would pose a risk to off-range receptors is unlikely.

5.0 CSM

After the completion of the data collection and extraction processes, a CSM was prepared for each operational range or range complex under assessment and depicted in either the Modeling Assumptions Package (MAP) or SAR Assumptions Package. The REVA CSM provided a description of the physical conditions of the operational range, a summary of the military munitions and corresponding indicator MC concentration loading table associated with the operational range, a preliminary identification of MC migration pathways and potential receptors, and identification of data gaps. The CSM provided a standard means to summarize and display what was known about the operational range and to document the assumptions and/or initial data interpretations.

Examples of specific CSM elements include the following:

- Soil types
- Geology description
- Groundwater flow direction
- Surface water features (e.g., lakes, streams)
- MC loading area(s)
- Potential human and ecological receptors

The included elements and format for the CSM were customized and tailored for each site in order to capture all pertinent information needed to describe the environmental conditions. The above-mentioned elements generally were included in a CSM; however, additional elements may have been necessary depending on the installation depiction. Appendix E contains CSM tables of elements for groundwater and surface water. These tables were used to assist in identifying necessary data elements to complete a site-specific CSM during the baseline assessments.

The CSM was provided to HQMC, TECOM, and the installation for review and concurrence prior to the modeling and data analysis effort. In addition, HQMC contacted a third party to review the CSMs for additional certainty and defensibility in the process.

The format of the REVA CSM was customized, as needed, to communicate the specific conditions of the operational ranges. In most cases, the information needed for developing a CSM was categorized into the following profiles.

- *Operational Range Facility Profile* described the features of and military munitions related activities conducted on the operational range.
- *Military Munitions and MC Profile* described the types and quantities (if known) of military munitions expended at the operational range and the concentrations of their associated fillers (i.e., indicator MC).
- *Physical Profile* described the physical factors that may affect release and fate and transport of MC.
- *Groundwater Profile* described the characteristics of the groundwater associated with the operational range.
- *Surface Water Profile* described the characteristics of surface water associated with the operational range.
- *Human Receptor and Exposure Profile* described uses of the land and ocean at and near MC loading areas that are used or accessed by identified human receptors.
- *Natural Resources Profile* described the ecosystems, vegetation, fauna, and special status species associated with MC loading areas and the relationship of the MC sources to habitat and potential receptors.

Each of the profiles is described below. A graphical CSM was provided for each installation during the baseline assessments. The CSM was a tool that evolved as site work progressed and data gaps were filled.

5.1 OPERATIONAL RANGE FACILITY PROFILE

The Operational Range Facility Profile included the boundaries of the operational range, showing the pertinent features, including firing points, target area, and impact areas. The current and historical military munitions related activities conducted on the operational range were included.

Other information included the following:

- History of the operational range area (e.g., How long has the range been in use? What were historical use areas?)
- Documented restrictions

- Ownership of the land/deeds
- Identification of major studies and initiatives conducted on the operational range area (e.g., PRA, ASR, INRMP, groundwater studies, cultural resource investigations)

5.2 MILITARY MUNITIONS AND MC PROFILE

The following information was included in the Military Munitions and MC Profile:

- Military munitions types and their quantities currently and historically expended at the operational range
- Quantity of indicator MC in each type of military munition expended on the operational range
- An estimate of the concentration of indicator MC loaded to the MC loading areas of the operational range (i.e., MC concentration table as described in Section 4)

5.3 PHYSICAL PROFILE

The Physical Profile described factors that influence potential migration of indicator MC into the subsurface. These factors included the following:

- Topographic and land cover (vegetation) features
- Surface and subsurface geology
- Soil types and properties
- Meteorological and climate data, including long-term quantitative information on precipitation and temperatures

5.4 GROUNDWATER PROFILE

The Groundwater Profile included the following information:

- Groundwater resource use locations (water supply wells on and off the installation) and all natural and artificial locations of groundwater discharge/ recharge
- Regional and local (if available) hydrogeologic information, such as depth to groundwater, presence of shallow and deep aquifers and aquitards, groundwater flow direction and rate, and aquifer characteristics
- Beneficial resource determination (such as classification of sole-source aquifers)

During work on the groundwater profile, particular attention was given to public and private water supply well characteristics, such as depth of well screen, pumping rate, type of aquifer, and the presence of confining layers (aquitards) above well intake areas. In some cases, when available, the groundwater profile was presented graphically with potentiometric surface maps, geologic/hydrogeologic cross sections, graphs, and diagrams to assist in communicating the conditions of the groundwater associated with the operational range.

5.5 SURFACE WATER PROFILE

The Surface Water Profile included the following information:

- Topography
- Delineation of major and minor drainage basins
- Surface water features and their classifications (e.g., streams, ditches)
- Surface water drainage patterns (runoff)
- Erosion potential
- Soil types
- Water balance
- Slopes

5.6 HUMAN RECEPTOR AND EXPOSURE PROFILE

The Human Receptor and Exposure Profile identified known human receptors associated with current and reasonable future land use on or near MC loading areas and the installation. It also described uses of the land and ocean in the area of MC loading areas that are used or accessed by identified human receptors.

5.7 NATURAL RESOURCES PROFILE

The Natural Resources Profile identified known T&E species and any additional known ecological receptors potentially impacted via identified pathways. T&E species were the primary focus for identifying ecological receptors; however, if specific sensitive species were identified in the area where a possible pathway was identified, they were individually researched to determine potential impact. This profile also described the ecosystems, vegetation, fauna, and special status species associated with MC loading areas and the relationship of the MC sources to habitat and potential receptors.

5.8 EXAMPLE CSM

The format for the CSM was customized for each operational range, as needed, in order to capture all pertinent information needed to describe the environmental conditions at the operational range. In general, the format for the CSM included text/tables and, where applicable, maps and GIS layers for spatial reference. Graphical depictions were also used to supplement the text CSMs. Figure 5.8-1 illustrates an example graphical CSM.

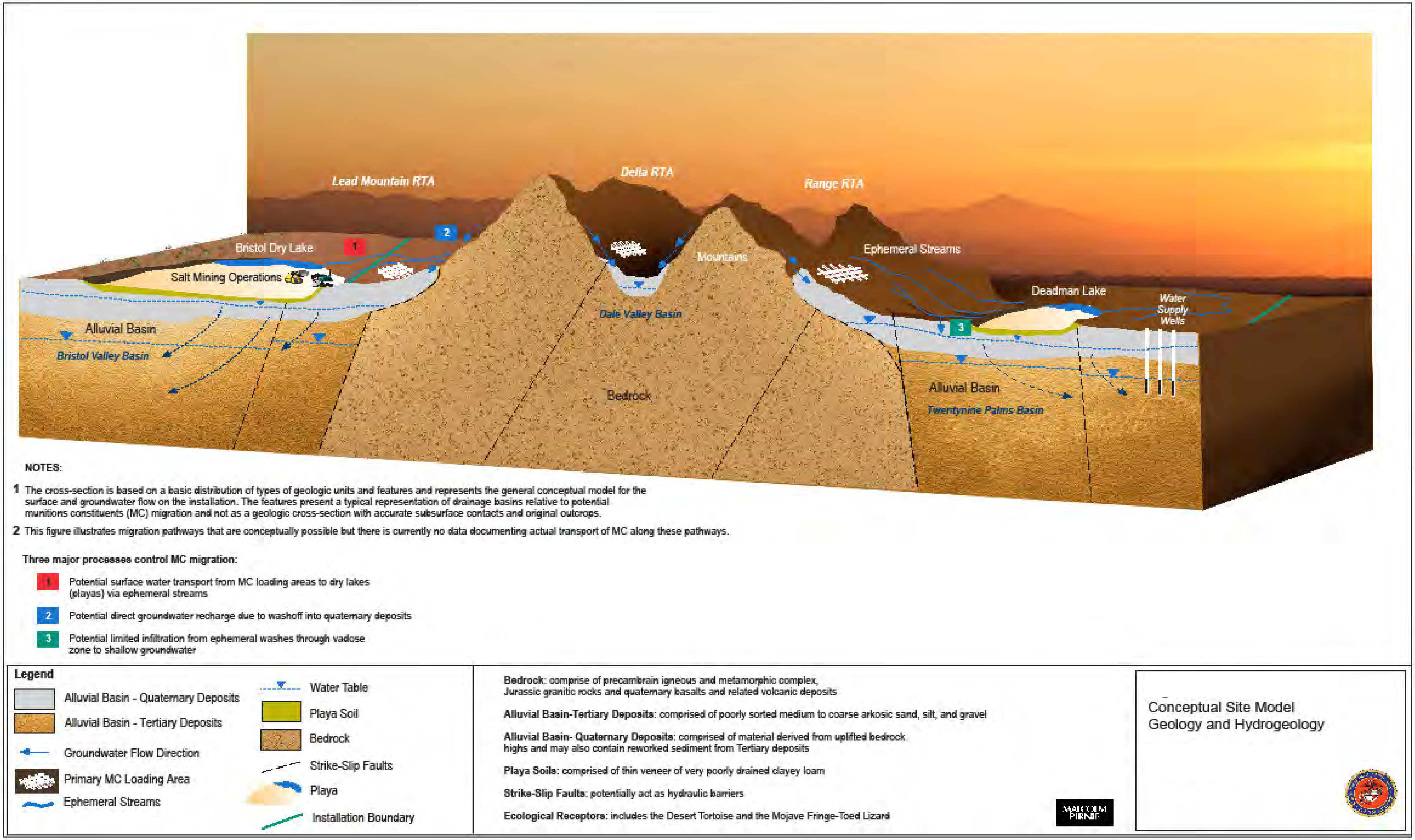


Figure 5.8-1: Example graphical CSM

6.0 FATE AND TRANSPORT MODELING

The REVA program was created to assess the potential of whether a release or substantial threat of a release of MC from an operational range to an off-range area poses an unacceptable risk to human health or the environment. Operational range-specific military munitions use and environmental data were collected during the baseline assessment and used in computer fate and transport screening-level models to assess the potential for release of REVA indicator MC. The fate and transport models were based on data inputs that define MC characteristics. The models also incorporated geophysical and geochemical parameters that were collected as part of the REVA process. Two potential release pathways were modeled in REVA during the baseline assessment: groundwater and surface water.

For modeling purposes, three historical time-based data sets were needed. The time-based data sets included:

- annual mass of each indicator MC (by type) expected to be accumulated at or near the soil surface; this mass was divided by the total point source and nonpoint source area, where applicable;
- total annual (and/or seasonal, where applicable) precipitation, together with the estimated infiltration rate as explained further in the text; and
- total annual (and/or seasonal, where applicable) contaminant flux from the soil surface for each indicator MC and each source type (point and nonpoint).

This section of the Reference Manual provides a definition for an off-range release, describes indicator MC, and outlines the fate and transport modeling approach for REVA during the baseline assessments.

6.1 IDENTIFICATION OF POTENTIAL MIGRATION SCENARIOS

REVA assessed the operational ranges throughout each Marine Corps installation. Three distinct scenarios might have occurred:

1) Predicted potential migration to adjacent operational range (range-to-range migration)
2) Predicted potential release to nonrange area within the installation boundary (e.g., cantonment area)

3) Predicted potential release off range to areas outside the installation boundary

The predicted potential migration scenarios are shown in Figure 6.3-1. The figure is a graphical representation of predicted potential MC migrations via groundwater from two hypothetical ranges (Range X-Ray and Range Bravo). Similar potential MC migration scenarios might also have occurred with surface water flows.

The predicted potential migration scenario is important in determining whether additional actions were considered or necessary. Predicted potential migration to adjacent operational ranges (Scenario 1) typically did not require a response action. A predicted potential release to nonrange area within an installation boundary (Scenario 2) may have required additional actions if a pathway and a receptor existed. A predicted potential MC release off range to adjacent areas outside the installation boundary (Scenario 3) would trigger a CERCLA response; however, this scenario was not encountered during the baseline assessments.

6.2 MC

As previously stated, the four REVA indicator MC modeled were TNT, RDX, HMX, and perchlorate. Lead is also an indicator MC; however, it was assessed qualitatively during the SAR assessments as described in Section 7.2. The DoD identified screening values for human and ecological receptors for the groundwater and surface water pathways. These values were compiled by the RMUS so that a consistent set of screening values could be applied to determine whether a release or a threat of a release of MC may cause an unacceptable risk to human health or the environment. These values were used when additional investigation was deemed necessary during the baseline assessments.

6.3 OVERALL MODELING APPROACH

All operational ranges in the inventory for the installation at the time of the baseline assessment were considered, although it may not have been necessary to model every operational range. In some cases, operational ranges were grouped together for modeling

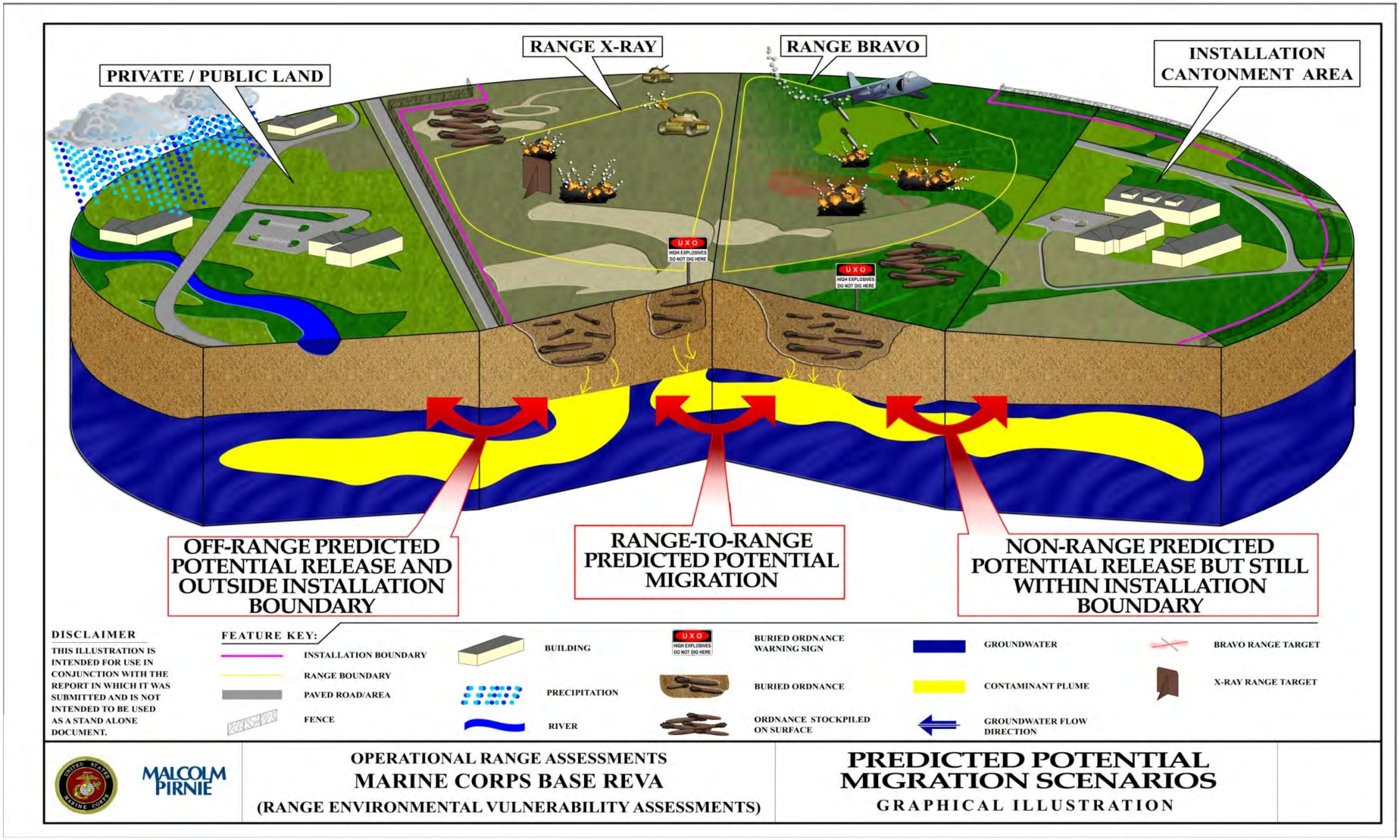


Figure 6.3-1: Predicted potential migration scenarios

purposes if they shared similar characteristics, including environmental characteristics and military munitions use. Areas that did not contain indicator MC were eliminated from further evaluation; the remaining area, as detailed in Section 4.3.6 was determined to be MC loading areas.

The baseline assessment utilized the process outlined below to determine which operational ranges / MC loading areas should be modeled. The operational ranges that had the highest risk of potential release underwent fate and transport groundwater and surface water modeling first. This effort was documented in the MAP for each specific installation. In addition, the MAP identified data gaps and their potential effects on the modeling. The MAP also outlined the installation-specific assumptions used for conducting the fate and transport modeling at the particular installation.

6.3.1 Determining Areas of Greatest Potential for Concern

In order to determine which operational ranges / MC loading areas represented the greatest potential for concern, or worst case, the MC loading on each operational range / MC loading area was considered. Ideally, MC loading calculations were performed for each operational range / MC loading area on the installation first. However, if data gaps or other factors delayed MC loading calculations, local knowledge of current and historical range usage by range operators and/or other installation personnel was used to identify which operational ranges / MC loading areas were believed to have the greatest potential for concern. The local knowledge was validated by the completion of the MC loading calculations, which may have continued in parallel with the operational range / MC loading area evaluations. Additional criteria such as the following were also used to determine which areas may have higher levels of MC loading: level of use, duration, size of MC loading area, and current status of the operational range.

6.3.1.1 MC Loading Criteria

Criteria such as the following were used to determine which areas may have higher levels of MC loading:

- The level of use analysis accounts for the intensity of training activities conducted at all ranges associated with the MC loading area. Levels of use were rated based on expenditure data, input from Range Management / Range Control, and professional judgment of the REVA Team. The more intense or higher the level of use, the higher the designation[3] of the area.
- The duration of MC loading accounts for the period of use of all operational ranges associated with the MC loading area. The longer the duration, the more adverse the expected affect on the environment and the higher the designation. (However, there may have been a relatively new operational range that received a short duration rating that was given a higher designation based on ongoing Marine Corps training requirements for the operational range(s) associated with that MC loading area.)
- The size of the MC loading area was evaluated to account for the dilution effect that larger sites have on the MC loading rates; the smaller the size of the MC loading area, the higher the designation.
- The current status of the operational ranges associated with the MC loading areas is simply an indicator of whether MC loading continues at the site. Status of an MC loading area was indicated as current or historical. This criterion helped determine if a site should be designated at a higher level. In most instances, operational MC loading areas had a higher initial designation; however, there may have been historical MC loading areas that had high designations as well.

6.3.1.2 Assessment of Environmental Characteristics

Environmental characteristics were assessed following the determination of which MC loading areas have the greatest potential for concern based on actual MC loading calculations. If necessary, the assessments of surface water and groundwater characteristics were conducted simultaneously to determine which operational ranges / MC loading areas have the greatest potential for concern based on specific environmental characteristics independent of MC loading results. The environmental characteristics were then analyzed and assigned an initial designation for modeling purposes based on increased potential of reaching a receptor, as described in the following sections.

Surface Water Characteristics: The primary surface water considerations used to help determine which MC loading areas had the greatest potential for concern relating to surface water only were the type and proximity of potential surface water receptors. MC

[3] The term "designation" indicates the priority of concern into which an operational range/MC loading area was placed.

loading areas that were near and up gradient of surface water drinking sources, including reservoirs and stream intakes, were given a higher designation. Potential ecological receptors in these streams were also considered significant if surface water was used for drinking water. For this reason, MC loading areas near perennial streams generally received a higher designation. Higher designations were also given to sites that were up gradient of developed areas with a higher potential for human contact with surface water (e.g., base housing).

Lower designations were given to sites farther away or down gradient of the potential receptors discussed above. Other reasons for lowering designations included discharge to only ephemeral streams or discharge to open tidal waters where a large amount of near-field blending could be inferred. Smaller tidal creeks generally are not used as drinking water sources, but do support potential ecological receptors. For this reason, an MC loading area that discharged to small tidal creeks may have been designated as an area of potential concern. The ability to quantitatively model the transport of MC in expansive tidal wetlands (e.g., salt marshes) is limited for the screening-level analyses employed in the baseline assessments. Therefore, such MC loading areas, if determined areas of potential concern, generally were recommended for assessment by other means, such as sampling or more detailed modeling beyond the scope of the baseline assessment

The potential for erosion and surface water runoff from MC loading areas was also considered. Sites with a higher potential for runoff included those with:

- less permeable soils (hydrologic groups C and D),
- more erodible soils,
- steeper slopes,
- less vegetation,
- more disturbance and compaction, and
- higher annual precipitation.

<u>Groundwater Characteristics:</u> Major groundwater characteristics considered in determining which MC loading areas had the greatest potential for concern relating to groundwater only were the following:

- Presence of an aquifer directly exposed to the recharge from land surface (unconfined aquifer)
- Direction of groundwater flow in the shallow (unconfined) aquifer
- Interactions between the shallow aquifer and the surface stream(s), such as gaining and losing streams and aquifer discharge/recharge areas influenced by the stream(s)
- Presence of groundwater wells or natural discharge points near the MC loading area and location of the nearest wellhead protection area, if applicable
- Interconnections between shallow aquifers and deeper aquifers that are or may be used for water supply
- Thickness of the unsaturated zone
- Type and permeability of the surficial soils

An example of an MC loading area with a higher designation for modeling is an underlying shallow aquifer with the thin unsaturated zone (high water table) composed of highly permeable sandy soils, which discharges into a surface stream with human and ecological receptors. Another example of an MC loading area with a higher modeling designation is the above-described shallow aquifer overlying a semiconfined regional aquifer used for public water supply. Thick (several tens of feet) surficial clayey soils and absence of aquifers used for water supply qualified the corresponding MC loading area for a lower designation.

<u>Conclusion:</u> Due to a variety of possible combinations of environmental characteristics, it was not desirable to explicitly list and qualify all of the characteristics considered in selecting operational ranges / MC loading areas for modeling. However, each installation report documents modeling area selections in detail.

6.3.1.3 Joint Consideration of Loading and Environmental Characteristics

An MC loading area that has extensive use may have been given a higher designation based on MC loading, but if it was not located near a potential receptor for surface water or groundwater, it was given a lower designation. On the other hand, an MC loading area that has been designated moderate based on the MC loading may have required modeling if it lay inside a designated wellhead protection area. The presence of a source-pathway receptor interaction was key in making these designations.

6.3.1.4 Necessity for Additional Areas to be Modeled

If the modeling results for the MC loading areas with potential higher designations predicted MC could reach receptors, then the lower designated areas may have been further assessed and modeled as well. In some cases, the higher designated MC loading areas may have been in an environmental setting too complex (e.g., interactions between multiple aquifers, pumping from multiple water supply wells) to use the REVA groundwater modeling approach outlined in the following sections. In such cases, these MC loading areas were recommended for further assessment (e.g., more detailed three-dimensional numeric modeling, sampling).

6.4 GROUNDWATER AND SURFACE WATER MODELING APPROACH

The approach to groundwater and surface water modeling, general assumptions and conditions, and outlines of individual model selections are explained in the following sections. Figure 6.4-1 summarizes the process flow for both groundwater and surface water modeling for the baseline assessments in REVA. The figure shows how the previously described “Determining Areas of Greatest Potential for Concern” was the first part of the overall modeling process after the CSM was developed. This overall modeling process flow diagram, along with the specific diagrams for the modeling processes described in detail in the following sections, demonstrates the complete REVA modeling process followed during the baseline assessments for installations where screening-level modeling was necessary.

6.4.1 Groundwater Modeling Approach and Assumptions

An overview of the REVA groundwater modeling process with respect to the assessment of the potential for MC releases from groundwater associated with operational ranges is outlined in Figure 6.4-2.

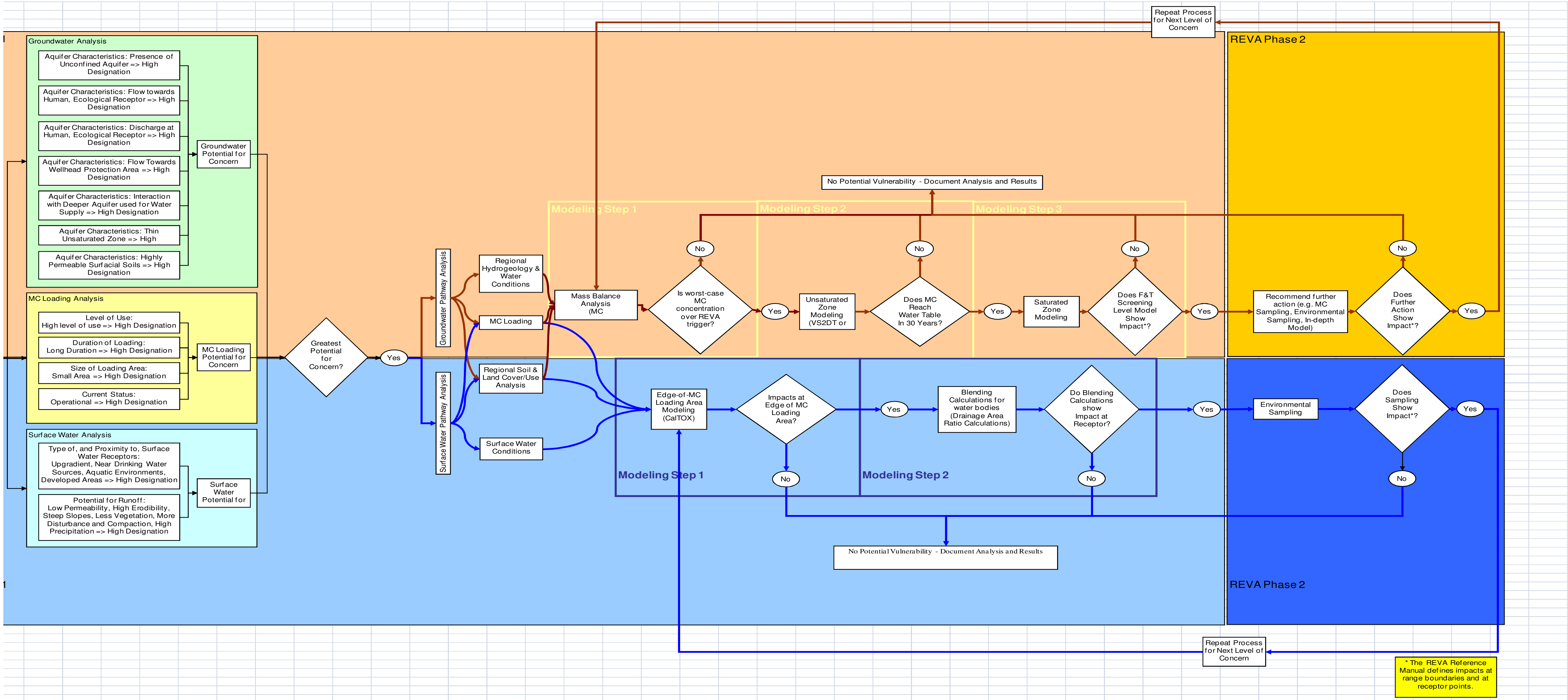


Figure 6.4-1: Modeling process flow diagram

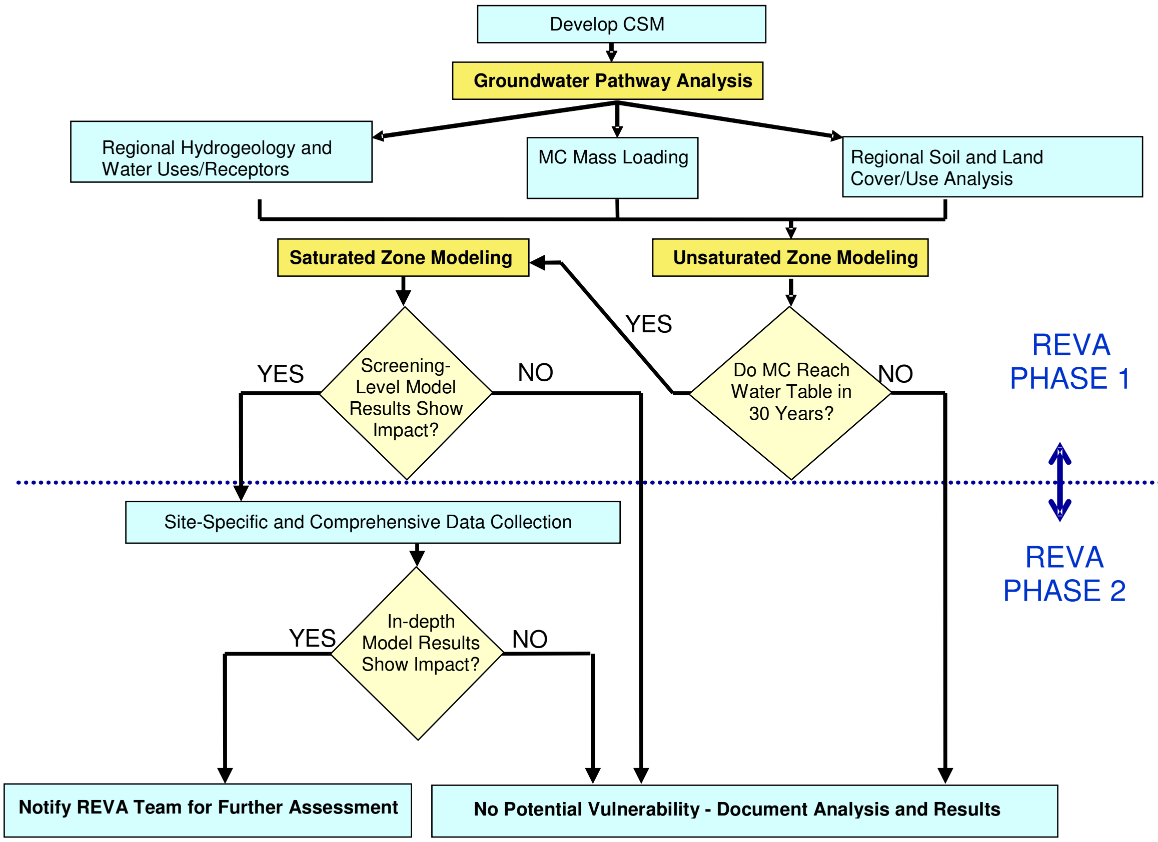


Figure 6.4-2: Groundwater modeling process

Groundwater analysis was first performed as a screening-level calculation of the average annual concentrations of indicator MC that may reach the groundwater table. The groundwater screening-level analysis was performed as a spreadsheet-based mass balance calculation. The basic input data were the estimated average annual MC loading rates of each MC to each identified MC loading area and the estimated infiltration amount of total annual precipitation of the area being assessed. The infiltration rate was selected based the specific soil characteristics of the area being assessed. An example of the mass balance calculation is demonstrated in Figure 6.4-3 with an estimated infiltration rate of 25%.

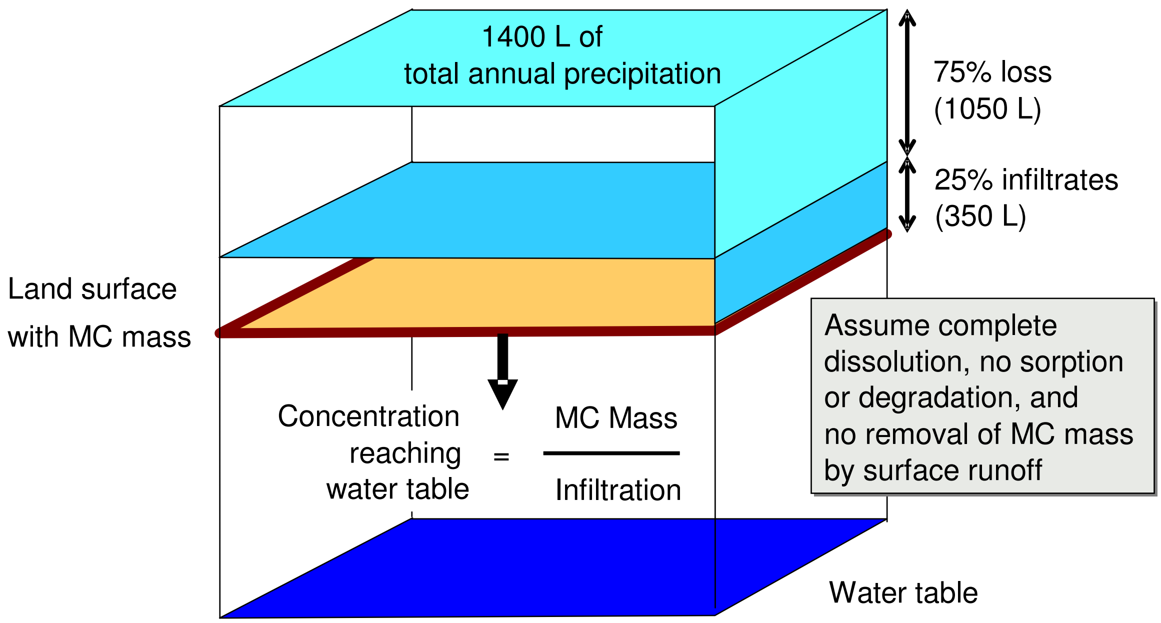


Figure 6.4-3: Screening-level mass balance calculation of potential dissolved concentrations of MC reaching the water table (L = liter)

If the screening-level analysis (shown above) indicates the potential for a modeled MC to reach the groundwater, then REVA Phase 1 modeling was initiated to assess potential MC migration in groundwater, as shown in Figure 6.4-2.

There are two phases to the groundwater screening-level modeling process for REVA. REVA Phase 1 began with the development of a CSM (Section 5) and collection of regional environmental data, such as hydrogeology, water uses/receptors, soil, and land cover/use analysis data required for the REVA Phase 1 models. Government or state agencies, such as the U.S. Geological Survey and state environmental protection agencies, commonly publish regional data. Assumptions were used and documented the installation REVA report in the cases where regional range data were missing or incomplete.

An unsaturated zone model was then completed to determine if the potential exists for MC to reach the surficial water table using a 30-year modeling window. A 30-year modeling window was selected to ensure protectiveness. The majority of indicator MC will degrade within 30 years; therefore, it was considered a reasonable screening window. In addition, the operational range assessment will be conducted every 5 years, so 30 years is six times the reassessment rate. If the unsaturated zone model showed that a potential existed for the MC to reach the water table, then a model for the saturated zone was processed to assess potential for horizontal migration off the operational range. Where available data existed on possible groundwater withdrawals near the operational range (e.g., pumping wells) and where the hydrogeologic conditions were simple (e.g., uniform porous media, one aquifer, no aquitards), a simple numeric model for the saturated zone was developed, when possible.

If REVA Phase 1 indicated the potential for MC migration from the operational range to an off-range area, then REVA Phase 2 may have been necessary. REVA Phase 2 modeling requires a more in-depth analysis, including gathering more detailed site-specific data to refine assumptions used in the REVA Phase 1 analysis and utilizing other available models as a cross check. The REVA Phase 2 modeling was not conducted during the baseline assessments completed to date, as other available options were determined to be more appropriate (e.g., sampling).

6.4.1.1 Groundwater Characteristics at Low-lying Island and Peninsula Areas

Shallow groundwater pathway analysis is complex for the low-lying island and peninsula areas because of the unique hydrologic and hydrodynamic aspects of these tidally influenced areas. In addition, they are surrounded by high salinity seawater, which would require sophisticated geochemical modeling in order to simulate/predict groundwater MC fate and transport. Therefore, groundwater pathway analysis in these tidally influenced areas was beyond the scope of the Phase I assessment under REVA.

6.4.1.2 Groundwater Fate and Transport Model Selection

During the baseline assessments, it was important to provide an accurate and reliable groundwater assessment. A review of various models was performed to determine those suitable for typical sites assessed under REVA.

Models were evaluated based on individual factors from the following six areas:

- Availability of licensing requirements and technical support
- Model validation and number of users
- Computational requirements
- Documentation quality
- Availability of flow and fate and transport parameters
- Availability of specialized options

6.4.2 Surface Water Modeling Approach and Assumptions

As with groundwater modeling, the surface water modeling process began with the development of the CSM to identify major surface water transport pathways (e.g., streams, ditches), uses, and regional data that help characterize the major hydrologic processes. Sites selected for quantitative modeling were based on the potential for elevated concentrations of MC that could affect human health or the environment. Phase 1 of the quantitative modeling involved estimation of MC concentrations in surface water runoff at the edge of the MC loading area. If this analysis predicted potential impacts, further calculations were performed to estimate the MC concentrations at a downstream receptor. This initially was performed by simple blending calculations, such as multiplication by drainage area ratios. If these calculations showed the potential for downstream impacts, additional actions were evaluated (i.e., specific ecological receptor literature research or sampling).

The primary purpose of the Phase 1 surface water screening is to predict whether MC concentrations likely would be detectable or nondetectable in surface water down gradient from MC loading sites. Typically, the screening-level calculations had to be performed with limited site information. Hence, results of the Phase 1 screening were considered conservative, order-of-magnitude estimates of MC concentrations in surface waters. These results were used to determine if additional modeling or sampling should be performed or, conversely, if the site was highly unlikely to impact surface water receptors. Therefore, surface water concentrations calculated using the screening methodology described herein were used for comparative purposes and for assessing the reasonable potential of a site impacting surface water receptors. Concentrations were not used for evaluation against water quality standards or goals.

The spatial and temporal resolution of the screening-level calculations was inherently set by the resolution of the input data. The modelers typically were provided with annual MC loading estimates. Hence, the results of the Phase 1 screening were interpreted as estimates of the annual average concentration at the point of interest, rather than the maximum concentrations that could occur at any time. Similarly, it was assumed that the annual MC loadings were applied evenly across the loading areas, even though in reality some subareas may have experienced higher or lower loadings/concentrations.

The surface water screening involved four different types of calculations, corresponding to the estimation of:

- annual volume of surface runoff from the MC loading site,
- annual mass of soil eroded from the MC loading site,
- annual mass and concentration of MC in surface water runoff from the MC loading site, and
- mixing of downstream MC in streams, lakes, or tidal waters.

For each of these types of estimates, it was desired to use relatively simple calculations as befitting a screening-level analysis with limited input data. However, it was also desired to use established methods that easily could be reproduced in future iterations of REVA. The methodology for each of these types of calculations is discussed in subsections below.

6.4.2.1 Estimation of Surface Water Runoff Volume

An estimate of the volume of surface water runoff from the MC loading site is required for subsequent estimation of the mass and concentration of the MC in surface water runoff from each loading site. For the Phase 1 screening, surface runoff was estimated using a variant of the rational method, in accordance with the following equation:

$$Q = C\ i\ A$$

Where:

Q = surface water runoff volume (acre-feet/year)
C = runoff coefficient (dimensionless)
i = average annual precipitation (feet)
A = area of loading (acres)

Average precipitation rates near Marine Corps installations were obtained from NOAA meteorological summary reports or calculated from local meteorological data. Runoff coefficients to be used with the rational method varied based on soil hydrologic group, slope, and land cover and were selected based on published tabular recommendations such as McCuen (1998) or local engineering manuals. Although the runoff calculation was inherently annual, it was re-expressed as an average daily runoff rate for use with the multimedia partitioning model (CalTOX), as further described below.

The multimedia partitioning model also required estimation of the groundwater recharge rate, which was obtained from local hydrologic studies or calculated as a proportion (e.g., 15%–30%) of the total annual precipitation.

6.4.2.2 Estimation of Soil Erosion

Estimates of soil erosion were required for subsequent calculations of the mass of MC transported from each site and were especially important for low solubility MC or those that strongly adsorb to soil. For the Phase 1 screening, annual soil erosion rates were estimated using the Revised Universal Soil Loss Equation (RUSLE), in accordance with the following equation:

$$A = R\ K\ L\ S\ C\ P$$

Where: A = estimated average soil loss (tons per acre per year)
R = rainfall-runoff erosivity factor
K = soil erodibility factor
L = slope length factor
S = slope steepness factor
C = cover-management factor
P = support practice factor

Rainfall-runoff erosivity factors vary greatly across the country and, thus, were estimated from local or state reports such as those published by the Natural Resources Conservation Service or local soil and water conservation districts. Soil erodibility factors were obtained directly from local soil surveys, and slope length and slope steepness factors were estimated from topographic maps. The cover management and support practice factors reflect the agronomic origins of RUSLE and typically were set to 1.0 for REVA applications. Additional description of RUSLE is provided by the U.S. Department of Agriculture, Agriculture Research Station (2003).

6.4.2.3 Estimation of MC Mass and Concentration in Surface Water Runoff

MC loaded into soil at a site may be expected to partition into various media over time. Some mass may volatilize, some may be leached downward into the unsaturated zone, some may remain in the upper soil zone, and some may be transported off site by surface water runoff. The manner and rate at which a particular MC will partition between these media are dependent upon the chemical properties of the MC and the physical/hydrologic properties of the site. Hence, a key requirement of the Phase 1 surface water screening was to estimate the multimedia partitioning of MC at the site, with an emphasis on estimating the mass and concentration of MC in surface water runoff from the MC loading site.

For REVA, the partitioning of MC mass into surface runoff at the site was estimated using CalTOX, a spreadsheet-based multimedia total exposure model that was developed by the California Department of Toxic Substances Control. The average annual MC concentration was then calculated as the annual MC mass in surface water runoff (obtained from CalTOX) divided by the annual surface water runoff volume (obtained from the rational method as described in Section 6.4.3). The following subsections provide additional details on how CalTOX was used to estimate the MC mass in surface water runoff.

6.4.2.4 Overview of CalTOX

CalTOX consists of a multimedia transport and transformation model and an exposure scenario model for conducting risk assessments. For the modeling of potential MC releases from identified MC loading areas, only selected elements of the multimedia transport and transformation model of CalTOX were used. The exposure scenario model was not used because quantitative risk assessment is not an objective of REVA. Similarly, CalTOX was not used directly to estimate MC concentrations or sediment deposition in surface waters down gradient of the loading areas. Rather, CalTOX was used only for estimation of the MC mass in surface water runoff from each loading area. Portions of CalTOX that do not influence the estimate of the mass of chemicals in runoff were not parameterized for REVA sites and, thus, cannot be interpreted to have meaningful output.

For example, after a chemical migrates below the surface soil, it is no longer available for runoff (dissolved or particulate). Therefore, CalTOX parameters reflecting behavior in the subsurface do not influence the mass in runoff. Similarly, the output from the CalTOX used in the REVA modeling is the mass of MC in the runoff from the site. CalTOX was not used directly to estimate the concentration of MC in surface water or any other surface processes.

CalTOX was chosen as a tool for the surface water screening because of the model's overall capability of simulating the major transport mechanisms (erosion of adsorbed MC in soil, direct dissolution in runoff, and leaching to the subsurface environment) that are likely to affect MC from their point of origin in surface soils to their release into surface runoff. Rather than being designed to simulate highly specific contaminants or hydrologic settings, the CalTOX model formulation is highly generic and flexible for use with many different chemicals and environments. As such, it can be applied to a variety of MC and at Marine Corps installations with very different landscape properties.

There are additional reasons for selecting CalTOX for the surface water screening analysis. The CalTOX modeling methodology relies on data typically available (annual loading rates, basic chemical and landscape information) without depending on data beyond the scope of a screening-level analysis, such as detailed hydraulics or in-stream sediment transport data. CalTOX is in the public domain, has good technical documentation (California Department of Toxic Substances Control, 1993), and is easy to use.

6.4.3 Modeling Sensitivity Analysis

The sensitivity of predicted surface water and groundwater concentrations to input parameters may be assessed by examination of the change in the output concentration that is caused by a change in the input parameter, with all other parameters held constant. For the purposes of this analysis, parameters to which output may be considered highly sensitive are those for which a one order-of-magnitude variation (i.e., a 90% change) would change the predicted concentration in surface water runoff or groundwater by 50% or more. Conversely, parameters to which output may be considered to have a low sensitivity are those for which a one order-of-magnitude variation would change the predicted surface water runoff concentration by 10% or less. Variation between 10% and 50% would indicate moderate sensitivity.

<u>Groundwater</u>

In the vadose zone models used to simulate the transport of MC from the land surface toward the saturated zone with shallow water table (such as VS2DI, VLEACH and HYDRUS), highly sensitive parameters are the infiltration rate and the unsaturated hydraulic conductivity. For thick vadose zones, such as in the western desert areas, additional highly sensitive parameters are the MC degradation rates and the retardation coefficient (sorption) due to long resident (travel) times. Generally less sensitive are porosity and dispersivity.

In the saturated zone groundwater models, both in those based on one-dimensional analytical fate and transport equations (such as Domenico equation utilized in Biochlor) and in numeric models describing horizontal groundwater flow, the most sensitive parameters are the initial MC concentrations in the saturated zone source area and the groundwater velocity (saturated hydraulic conductivity, hydraulic gradient, and effective porosity). Depending on groundwater travel times between MC mass loading areas and potential receptors (range boundaries), the MC degradation rates, contaminant retardation (sorption), and dispersivity may have moderate to high sensitivities. The low sensitivity input parameter is aquifer recharge.

Sensitivities of the model to groundwater parameters were estimated using a VS2DTI model of RDX at a Marine Corps EOD range. This site was chosen because of sufficient data and the existence of three monitoring wells just down gradient of the MC loading area. These three wells were sampled for MC in a 2005 sampling event, so the model results could be compared to field measurements. The parameters used in the sensitivity analysis were hydraulic conductivity, MC loading rate, and recharge. The model proved to be more sensitive to hydraulic conductivity than to the MC loading rate and recharge.

The sensitivity analysis yielded a range of predicted concentrations in the monitoring wells, and the measured values fell within that range. Further, if the wells had been an important off-site human health or ecological receptor, the REVA process would have correctly designated the EOD range as an area of potential concern. This inspires confidence in the REVA process and results when conservative parameter values are used in screening-level models.

The sensitivity analysis for recharge indicates the need to use ranges of parameter values (instead of a single conservative value) in the models to ensure that all areas of potential concern are identified. It is not easy to determine what recharge value would indicate a conservative estimate because of the complex effect of recharge on the concentrations at the well. A high recharge value will dilute the MC, resulting in lower concentrations, but it will also force the plume deeper by increasing the vertical gradient. Conversely, a low recharge value will result in a higher MC concentration in the recharge water, but will keep the plume closer to the surface. For the modeled operational range, the low recharge value left the bottom of the monitoring well below the plume, diluting the concentration measured at the well more than expected. If the well screen had been located differently, the results of the sensitivity analysis would have been different. The use of the highest or lowest reasonable value will not always result in the worst-case scenario at the receptor. Accurate designation of ranges of potential concern is most likely when a range of reasonable parameter values is used in the analysis.

Surface Water

Sensitivity analysis was carried out for the Phase I surface water screening-level analysis used to evaluate MC concentration in surface water runoff leaving MC loading areas. The input parameters were systematically varied, and the effect that each parameter change had on the change in the predicted concentration in surface water runoff was determined. Results are summarized in Table 6.4-1.

The parameter to which predicted surface water concentrations were most sensitive was the MC mass loading in operational range impact areas. Predicted concentrations in surface water runoff were also highly sensitive to four input chemical properties: molecular weight, octanol-water partition coefficient, Henry's law constant, and reaction half-life in surface soil. Of these four parameters, MC molecular weight was the most influential parameter, leading to a 1:1 change between the predicted concentration and the parameter (i.e., a 90% change of the parameter led to a 90% change in the predicted concentration). The next most highly important parameter describing chemical properties was the octanol-water partition coefficient, followed by reaction half-life in surface soil and the Henry's law constant. Most of the basic chemical properties of MC—including molecular weight, octanol-water partition coefficient, and Henry's Law constant—are well known and can be obtained from literature. The reaction half-lives in soil can be expected to vary from site to site, but suggested values were obtained for TNT, HMX, and RDX from subject matter experts based on a compilation of literature reviews (Appendix F).

Predicted concentrations in surface water were highly sensitive to three parameters that describe environmental factors of the landscape media: the MC loading area (contaminated area), surface water runoff coefficient, and groundwater recharge rate. MC loading area was the most influential landscape parameter, leading to a 1:1 change in the predicted concentration (Table 6.4-1). The next most important landscape parameter was the runoff coefficient, followed by groundwater recharge. MC loading rates and loading areas are defined prior to modeling and are not varied. Surface water runoff coefficients may be estimated with some confidence from land use/cover and topographic information. Similarly, groundwater recharge rates can be estimated as a proportion of annual precipitation data, considering evapotranspiration, surface water runoff rates, and soil permeability. They may also be obtained from regional hydrologic or hydrogeologic studies.

Input parameters to which predicted concentrations were moderately sensitive included the diffusion coefficient in pure air and water, plant dry mass inventory, plant dry mass fraction, erosion of surface soil, organic carbon fraction in soil, and the yearly average wind speed. Diffusion coefficients for MC are available from the literature. Under the Phase I screening-level methodology, soil erosion rates were calculated explicitly using information from soil surveys, which were also used to estimate the organic carbon fraction in soil. The average wind speed may be obtained from local climatological records. All the highly influential input parameters and a majority of the moderately influential input parameters of the CalTOX Phase I surface water screening-level analysis model are parameters that can be obtained from available sources (such as literature references, site-specific data, soil survey reports, site topography, land cover, and hydrography) and, thus, the confidence level of the use of these parameters is relatively high. Little information typically is available for plant mass parameters, so conservatively low values should be selected for these parameters in order to minimize the effect of plant pathway on the predicted concentration.

Parameters of low sensitivity were mostly those associated with air, sediment, surface water, and subsurface zone that do not directly impact mass transfer rate of MC from surface soil to surface runoff water (Table 6.4-1).

Table 6.4-1: Percent Change in Predicted Concentration in Surface Water Runoff as a Function of a 90% Change in each Parameter

CalTOX Parameter	Percent Change in Predicted Concentration
Molecular weight (g/mol) (MW)	90
Octanol-water partition coefficient (K_{ow})	85
Melting point (K) (Tm)	4
Vapor Pressure (Pa) (VP)	5
Henry's law constant (Pa-m^3mol) (H^-)	57
Diffusion coefficient in pure air (m^2/d) (D_{air})	13
Diffusion coefficient in pure water (m^2/d) (D_{water})	23
Plant Partition coefficient (abv-grd)/sl (kg[s]/kg[pFM] (Kps^-)	< 1
Bio transfer factor, plant/air (m^3[a]/kg[pFM]) (Kpa^-)	2
Bio transfer factor; cattle-diet/milk (d/L) (Bk^-)	< 1
Bio transfer factor; cattle-diet/meat (d/L) (Bt^-)	< 1
Bio transfer factor; hen-diet/eggs (d/L) (Be^-)	< 1
Bio transfer factor; brst mlk/mthr intake (d/kg) ($Bbmk^-$)	< 1
Skin permeability coefficient (cm/h) (Kp_w^-)	< 1
Fraction dermal uptake from soil ($dfct\_Sl^-$)	< 1
Reaction half-life in air (d) (Thalf_a)	< 1
Reaction half-life in surface soil (d) (Thalf_g)	75
Reaction half-life in root-zone soil (d) (Thalf_s)	2
Reaction half-life in vadose-zone soil (d) (Thalf_v)	< 1
Reaction half-life in ground water (d) (Thalf_q)	< 1
Reaction half-life in surface water (d) (Thalf_w)	< 1
Reaction half-life in sediments (d) (Thalf_d)	< 1
Load to surface soil (mol/d) (Sg)	90
Contaminate area (m^2) (Area)	90
Land surface runoff coefficient	83

CalTOX Parameter	Percent Change in Predicted Concentration
Atmospheric dust load (kg/m^3) (rhob_a)	5
Deposition velocity of air particles (m/d) (v_d)	3
Plant dry mass inventory (kg[DM]/m^2) (bio_inv)	18
Plant dry-mass fraction (bio_dm)	11
Plant fresh-mass density (kg/m^3) (rho_p)	< 1
Groundwater recharge (m/d) (recharge)	60
Evaporation of surface water (m/d) (evaporate)	< 1
Thickness of ground soil layer (m) (d_g)	< 1
Soil particle density (kg/m^3) (rhos_s)	6
Water content in surface soil (beta_g)	4
Air content in surface soil (alpha_g)	2
Erosion of surface soil (kg/m^2-d) (erosion_g)	30
Thickness of root-zone soil layer (m) (d_s)	< 1
Water content in root-zone soil (beta_g)	< 1
Air content in root-zone soil (alpha_g)	< 1
Thickness of vadose-zone soil layer (m) (d_v)	< 1
Water content in vadose-zone soil (beta_v)	< 1
Air content in root-zone soil (alpha_v)	< 1
Thickness of the aquifer layer (m) (d_q)	< 1
Solid material density in aquifer (kg/m^3) (rhos_q)	< 1
Porosity of aquifer zone (beta_q)	< 1
Fraction of land surface in surface water (f_arw)	< 1
Average depth of surface water (m) (d_w)	< 1
Suspended sediment in surface water (kg/m^3) (rhob_w)	< 1
Suspended sediment deposition (kg/m^2/d) (deposit)	< 1
Thickness of the sediment layer (m) (d_d)	< 1
Solid material density in sediment (kg/m^3) (rhos_d)	< 1
Porosity of the sediment zone (beta_d)	< 1
Sediment burial rate (m/d) (bury_d)	< 1
Ambient environmental temperature (K) (Temp)	4
Organic carbon fraction in upper soil zone (foc_s) when MC modeled is TNT	28
Organic carbon fraction in upper soil zone (foc_s)	7

CalTOX Parameter	Percent Change in Predicted Concentration
when MC modeled is RDX	
Organic carbon fraction in upper soil zone (foc_s) when MC modeled is HMX	< 1
Organic carbon fraction in upper soil zone (foc_s) when MC modeled is perchlorate	< 1
Boundary layer thickness in air above soil (m) (del_ag)	< 1
Yearly average wind speed (m/d) (v_w)	18
Darcy velocity (m/d) (v_darc)	< 1
Water dispersion coefficient (m^2/d) (D_T)	< 1

Note:
Pink highlight indicates highly sensitive parameter.
Blue highlight indicated moderately sensitive parameter.
No highlight indicates low sensitive parameter.
d:day
kg: kilogram
k: degrees Kelvin
m: meter

7.0 DATA ANALYSIS

This section of the Reference Manual discusses the analysis process used for the baseline assessments in REVA. For each installation, these included:

- fate and transport screening-level modeling of operational ranges and training areas,
- SAR assessments of defined SAR areas and evaluations for potential lead migration and exposure using the SARAP, and
- further assessments needed to collect additional information to assess identified MC areas.

7.1 ANALYSIS OF FATE AND TRANSPORT SCREENING-LEVEL MODELING RESULTS

7.1.1 Goal and Purpose of Modeling

The primary goal of the predicted screening-level modeling results was to provide information to determine whether further assessment was necessary to determine whether the potential for a release or substantial threat of a release of MC from an operational range to an off-range area was possible and whether such a release may pose an unacceptable risk to human health or the environment. For this to occur, two conditions had to be met. First, the possibility that predicted MC concentrations above the established REVA trigger values had to result from the modeling outputs. Second, a pathway and receptor interaction also had to exist. The process of determining if these two conditions were met was broken down into four distinct steps.

1. Identify if the predicted model output showed concentrations above the established REVA trigger values.
2. Identify whether any receptors (human or ecological) exist.
3. Identify whether pathways exist from the predicted release area to the receptors.
4. Identify whether there was interaction between the predicted release area and identified receptor through any identified pathway.

These four steps are discussed in more detail below following a summary of the background site knowledge required to support these data.

7.1.2 Background Site Knowledge

The fate and transport screening-level models provided an initial assessment of the potential spatial distribution of MC concentrations off the operational range in cases where the concentrations were higher than the REVA trigger values (i.e., method detection limit [MDL]). In order to analyze these data, the following background site conditions had to be known.

- Spatial data: the location of the operational range being assessed with respect to the off-range areas (i.e., how close is the operational range in all directions to the off-range area / installation boundary)
- Geology and hydrogeology: level of understanding of the regional and local geology and hydrogeologic framework (e.g., three-dimensional relationships among area aquifers, aquitards, bedrock, groundwater flow directions in different aquifers, groundwater recharge, and discharge zones)
- Potential receptor intakes: the spatial (three-dimensional) position of the potential receptor's groundwater intake relative to the hydrogeologic framework (e.g., well screen is in the deeper aquifer, separated from the shallow aquifer by an aquitard; well is on the other side of a strong hydraulic boundary such as a major permanent surface stream) or has a direct surface water intake
- Hydraulic gradient: an understanding of the regional and local groundwater hydraulic gradient in the area of interest, such as actual measured field data on groundwater elevation / hydraulic head in the area aquifers
- Aquifers and aquitards: an understanding of the aquifer(s) and aquitard(s) characteristics, such as field-determined numeric parameter values and spatial distribution of hydraulic conductivity or transmissivity

7.1.3 REVA Trigger Values (i.e., MDLs)

Although the REVA groundwater and surface water screening-level modeling approaches were designed to provide a realistically conservative estimate of the MC concentrations at the range boundary (or other location of interest), as an additional conservative approach, the screening-level modeling results were compared to realistically conservative laboratory MDLs to determine if the concentrations were significant enough to warrant further analysis/assessment. Although the MDLs vary from laboratory to laboratory, they were selected for comparison to the predicted modeled MC concentrations for conservativism. The trigger values for indicator MC were developed by obtaining MDLs from certified analytical laboratories. Certified analytical laboratories were contacted to obtain MDLs for typical energetic analytical methods being performed in the laboratory on an ongoing basis (as of early 2006). Reviewing the MDL data set collected from certified laboratories, the median representative MDL was used for each MC listed in Table 7.1-1 to assess predicted screening-level modeling results of MC that may be present in surface water or groundwater at a given distance from the MC loading area or source.

The U.S. Environmental Protection Agency (EPA) defines MDL as "the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero." In other words, detection above MDL for a given constituent simply indicates that the constituent was present in a sample analyzed by the laboratory. The confidence does not apply to the numerical value provided; thus, detection above the MDL does not necessarily mean that the detected constituent was present at the numerical value provided, but simply that it *was present* in the analyzed sample.

There are important qualifiers to understand when comparing predicted screening-level modeling results to MDLs. MDLs are not uniform among constituents, nor do they remain constant for a given constituent. An MDL is dependent on the analytical method employed to evaluate samples, as well as the technical capabilities of a given laboratory facility. As a result, MDLs that may be obtained by one laboratory may differ from those obtained by another; MDLs may even vary between facilities that are part of the same company, despite using similar analytical methods. Because actual MDLs change periodically, laboratories typically update MDLs on a yearly basis to reflect accurate values.

Table 7.1-1 presents 2006 MDLs for MC provided by several California laboratories. It was developed by contacting a single certified facility for each laboratory analytical company and acquiring current MDLs for the indicator MC. Since predicted screening-level modeling results were compared to MDLs to provide an indication of whether MC may be present at a given receptor, the most conservative approach would have been to compare the predicted screening-level modeling results to the *lowest* MDL reviewed for that constituent, regardless of laboratory. However, MDLs vary from laboratory to laboratory based on present techniques, capabilities, and instrument performance. If additional analysis/assessment (further detailed below in the Reference Manual) was carried out to confirm predicted screening-level modeling results, comparison to lowest MDLs available would not have been valid for examining predicted screening-level modeling results; therefore, a variety of laboratories was researched to determine MDLs for each indicator MC. In order to compare predicted screening-level modeling results to a reasonable threshold value, the median value of the investigated MDLs was determined as the REVA trigger value.

Table 7.1-1: May 2006 Comparison of Laboratory MDLs (Water)

TNT		HMX		RDX		Perchlorate	
Lab	**TNT**	**Lab**	**HMX**	**Lab**	**RDX**	**Lab**	**Perchlorate**
GPL	0.03	STL	0.036	STL	0.036	GPL	0.132
STL	0.05	Analytical Laboratory Service	0.070	Paragon Analytical	0.064	STL	0.339
Paragon Analytical	0.07	Paragon Analytical	0.073	Analytical Laboratory Service	0.070	Analytical Laboratory Service	0.800
CAS	0.08	CAS	0.080	GPL	0.160	CAS	0.980
Analytical Laboratory Service	0.09	GPL	0.190	TriMax	0.177	Sequoia Analytical/Test America	1.200
TriMax	0.11	TriMax	0.192	CAS	0.300	TriMax	1.860
Sequoia Analytical/ Test America	1.50	Sequoia Analytical/ Test America	1.500	Sequoia Analytical/ Test America	1.500	Paragon Analytical	2.630
Calscience	24.41	Calscience	30.990	Calscience	40.740	Calscience	4.896
Median MDL	**0.08 (CAS)**		**0.08 (CAS)**		**0.16 (GPL)**		**0.98 (CAS)**

Note:

All values are in parts per billion (ppb).

The median does not include Calscience's values.

STL MDLs were used as the preliminary MDLs during the REVA process.

While exceptions may exist, the typical analytical methods employed by laboratories include EPA Method 8330 for explosives and EPA Method 314 for perchlorate.

Lead was not modeled. MDLs will be applied from the laboratory that analyzes sample results. Note that the EPA action level for lead in drinking water (tap) is 15 ppb.

Therefore, the REVA trigger values to which REVA baseline assessment predicted screening-level modeling results were compared are the following:

- TNT 0.08 ppb
- HMX 0.08 ppb
- RDX 0.16 ppb
- Perchlorate 0.98 ppb

7.1.4 Determining the Potential for Predicted Migration or Release

The general process for determining the release or migration potential used during the baseline assessment is outlined below and shown in Figure 7.1-1. The term “plume” used in this section is meant to refer to possible MC transport in both assessed pathways: surface water and groundwater.

1. Compare predicted screening-level modeling output concentrations to REVA trigger values. If the predicted screening-level modeling outputs are above the trigger value, then continued to Step 2.
2. Understand the difference between a predicted potential migration and a potential release (see Figure 6.1-1).
   - Migration—if the predicted modeled MC concentration is predicted to go from an operational range to another operational range (i.e., potential range-to-range migration)
   - Potential release—if the predicted modeled MC concentration is expected to go from an operational range to a nonrange area, but still within installation (e.g., cantonment area, drinking water supply well)
   - Potential release—if the predicted modeled MC concentration is expected to go from an operational range to an off-installation area
3. If a potential release is determined in Step 2, then determine whether the predicted potential release is possible according to the operational range boundary and predicted MC plume:
   - Compare projected/predicted MC plume map with range/installation boundary or receptor point.
   - Distinguish between predicted potential release (crosses range boundary or reaches receptor point) and predicted substantial threat of a release (approaching range boundary or receptor point).

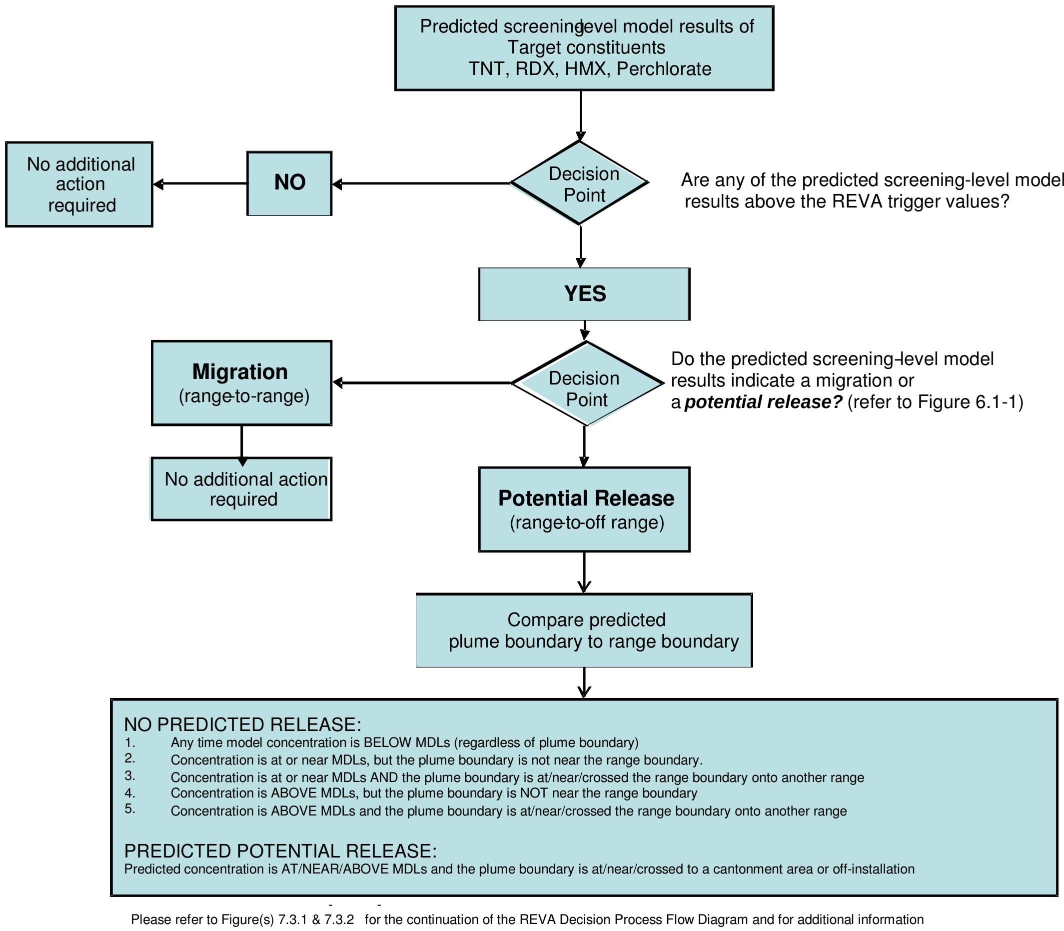


Figure 7.1-1: Flow diagram for determining migration or release potential

The fate and transport groundwater screening-level models predicted if the potential existed for MC to reach the saturated zone (i.e., groundwater) based upon the operational range conditions and on the types and amounts of MC estimated to be distributed over the operational range. If the potential existed for the MC to reach the saturated zone, the models also provided an estimate of the time of the MC concentration to reach identified receptors and/or the operational range boundary, while the surface water screening-level models predicted whether MC concentrations above trigger values would or would not reach identified receptor points in surface runoff. The accuracy of this analysis was based, in part, on the experience of the hydrogeologist and the level of detail/information known about the site that was available during the baseline assessment. In some cases, it was necessary to make assumptions regarding the specific conditions at the site. These assumptions introduced a level of uncertainty into the results. If this uncertainty was too significant or if the data element was critical to the analysis, specific targeted geophysical field sampling may have been required to provide more accurate results (for example, a monitoring well may have needed to be installed). If and when these focused projects were conducted, they were driven by the predicted screening-level modeling results and the level of confidence required.

The predicted potential MC concentrations were analyzed along with the boundaries of the operational range to determine if the MC crossed the range boundary, thus resulting in a potential migration or release of MC. Since the baseline assessments were done using a range-by-range approach, three distinct scenarios may have occurred, as described earlier.

- Scenario 1: Predicted potential migration to adjacent operational range (range-to-range migration)
- Scenario 2: Predicted potential release to nonrange area within installation boundary (e.g., cantonment area, drinking water supply well)
- Scenario 3: Predicted potential release off range to adjacent areas outside the installation boundary

The predicted potential release scenario was important with respect to response actions to be considered. MC migration to adjacent operational ranges typically *did not* require a response action (Scenario 1). The predicted MC migration concentration was taken into consideration when the operational range being affected by the migrating contamination was assessed, where applicable. A predicted potential MC release to nonrange area within an installation boundary (Scenario 2) may have necessitated a response action if a pathway and receptor existed (e.g., installation personnel). A predicted potential MC release off range to adjacent areas outside the installation boundary (Scenario 3) would have triggered a CERCLA response action after conducting further assessments confirming an actual release. If a CERCLA response action was required to address the MC release, the REVA data could be used to augment data requirements of the response action. However, no CERCLA response action was necessary during the baseline assessments.

If predicted MC concentration screening-level model estimates were higher than REVA trigger values, further evaluation of the potential risks associated with site contaminants was necessary. The fate and transport screening-level modeling assisted in determining the best location for collecting environmental samples to confirm the results, as needed.

7.1.5 Identifying Potential Receptors

Receptors were defined during the baseline assessment as human and biota that were exposed, or that may have been exposed, to MC potentially released from the operational range being assessed. The general information used to assist in identifying potential receptors is outlined below.

- Types of receptors considered
  - Human
  - Ecological
- Receptor pathways assessed
  - Surface water
  - Groundwater
- Data sources used identify receptors included (see Section 3)
  - Well permits (e.g., state and county records)
  - Well logs
  - INRMP
  - Biological assessments
  - IRP investigations, studies, or reports

Depending on the predicted screening-level modeling results and subsequent analyses, detailed analyses of receptors may have been conducted. The process of identifying receptors involved reviewing readily available documents and conducting interviews with installation personnel (see Section 3). In some instances, it was necessary to conduct a visit to the operational range to identify potential receptors. All potential receptors were identified during this process. The potential for the receptor to be impacted was assessed during the pathway/receptor interaction analysis discussed later in this section.

The REVA baseline assessment identified potential off-range receptors. As a guide, the immediate surrounding area and the area associated with the predicted potential release area were analyzed for potential receptors. Particular attention was placed on the area or limits of the predicted potential MC plume, as described above. The predicted MC plume was based, in part, on assumptions and best available data at the time the screening-level modeling was conducted. Therefore, a reasonable determination was made regarding the distance from the assessed boundaries for which the presence of receptors was identified. Having a comprehensive list of receptors allows for future analysis to be conducted more easily. For example, if the site conditions or the screening-level modeling assumptions change, thus causing the resulting predicted potential MC plume to change, then the new predicted plume can be compared to the comprehensive list of receptors without having to go through the entire receptor identification process again.

The following was minimal information necessary to assess receptors: receptor type (e.g., human), receptor identifier (e.g., residents), the activities conducted by the receptor or the potential resources used that could cause the receptor to come in contact with MC, and the information source where the receptor data were obtained (including date of the source). The level of detail available on each receptor typically varied. The extent to which the data are known was documented as part of the REVA or a reference to the source of the information was noted.

Potential receptors change over time; therefore, the list of potential receptors for each operational range should be kept up to date as conditions on or around the site change. For example, if a new housing area is proposed along the installation boundary, receptors may need to be added to the list. If future screening-level modeling efforts are conducted, the list of potential receptors should be reviewed and updated as appropriate.

7.1.6 Identifying Potential Pathways

A pathway is the environmental medium or matrix through which MC migrate to reach potential receptors. Groundwater and surface water were the environmental pathways included in the REVA baseline assessment. The potential soils pathway was captured within the groundwater and surface water analyses since all potential receptors exposed to the soil pathway are only temporarily exposed to potentially contaminated soils. The potential effect of inhalation of contaminated soils was not included in the baseline assessment since no known receptors are permanently located on operational ranges; therefore, inhalation is not expected to be a potential pathway of concern. A brief discussion of each pathway is presented below. The biotic pathway (uptake, accumulation, or concentration of contaminants by organisms and subsequent transport of contamination through the food chain) was not considered during the baseline assessments. The assessment was to determine whether a release or substantial threat of a release of MC from an operational range to an off-range area posed an unacceptable risk to human health or the environment. Risk assessments may have been necessary as additional actions, but were not conducted in conjunction with the REVA baseline assessment. Instead, available DoD RMUS screening levels were used for comparison.

Groundwater pathways may have existed if MC had the potential to impact groundwater by percolating through site soils into the aquifer(s) used for drinking water supply. Wells near operational ranges were identified. Screening-level modeling of MC through the saturated zone was carried out only if results of the unsaturated zone screening-level modeling (Section 6) showed there was a potential for the dissolved MC to reach the water table aquifer within the timeframe of interest. If receptors had access to groundwater for reasons other than as a drinking water source, these pathways were also assessed.

Surface water pathways may have existed if there was a potential for MC to impact surface water through either direct or indirect routes. MC may have impacted area surface water if there was a potential for direct runoff of MC from the operational range to the surface water body. MC may have been impacted surface water indirectly if a groundwater pathway existed and the groundwater was a recharge source for the surface water body. In order to fully assess the potential for a surface water pathway to impact a receptor, the uses of the surface water body, the drainage/discharge directions, tidal actions, and currents had to be known.

Surface water body sediment pathway. If a surface water pathway exists, there is also a potential pathway through sediments of the surface water body that may have accumulated settling MC. The physical characteristics of the MC were examined to determine if there is a potential for settling into sediments (i.e., nonsoluble). If MC had the potential to settle into sediments, a pathway may or may not have existed, depending on how the sediment relates to the surface water body and potential sediment accumulation areas. Sediment pathways were not modeled for the baseline assessment, but were considered as part of the surface water analyses.

Potential air pathway. The air pathway was not expected to be a viable pathway relating to operational range use (See Section 4.5).

7.1.7 Pathway and Receptor Interaction Analysis

Pathway/receptor interaction analysis involved reviewing each potential receptor and each identified pathway side-by-side to determine if the potential existed for the predicted MC to reach or affect the receptor through the identified pathway. Particular attention was paid to water wells that were used as sources of drinking water, in addition to nearby surface water bodies (e.g., intermittent streams, creeks, drainage swales).

For the purposes of documenting and communicating the results of the interaction analysis, the following descriptors were used.

- No receptor/pathway interaction was identified.
- Potential receptor/pathway interaction exists.
- Receptor/pathway interaction exists.

7.2 SMALL ARMS RANGE ASSESSMENT

The potential for MC to migrate from operational SARs poses an environmental vulnerability for outdoor SARs across the Marine Corps. MC associated with small arms ammunition commonly used at operational ranges include lead, antimony, copper, and zinc. The baseline assessment focused on lead as the indicator MC for SARs because lead is the most prevalent (by weight) potentially hazardous constituent associated with small arms ammunition. At the time of the SAR assesments, within the scientific community it was known that metallic lead (such as recently fired, unweathered bullets and shot) generally had low chemical reactivity and low solubility in water and remained relatively inactive in the environment under normal conditions. If the right combination of conditions existed, a portion of lead deposited on a range could become environmentally active.

Fate and transport parameters for lead at SARs are dependent on site-specific geochemical properties, which cannot be determined solely by physical observation. Therefore, ranges that solely utilized small arms ammunition (defined as nonexplosive ammunition, .50-caliber or smaller) for training purposes were assessed qualitatively under the REVA program. In addition, only operational SARs were addressed using this protocol; historical use SARs that are no longer used were not assessed due to lack of information to adequately perform an assessment.

The SARAP was developed as a qualitative approach to identify and assess factors that influenced the potential for lead to migrate from an operational range. These factors included the following:

- Range design and layout
- Physical and chemical characteristics of the area
- Past and present operation and maintenance practices

In addition, potential receptors and pathways were identified. A determination was made regarding the potential for an identified receptor of the SAR potentially to be affected by possible lead migration. The AEC currently is conducting a variety of studies relating to lead; to date, no results have been published. For operational ranges being assessed, the estimated amount of lead, along with other MC, expected to have been loaded to the operational ranges was determined, but no specific quantitative conclusions can be made regarding the fate and transport of lead until additional information is determined via site-specific data.

The SARAP and evaluation forms for Tables 1 through 6 are included in Appendix C.

7.3 FURTHER ASSESSMENT

If it was determined that further assessment was needed to identify whether an actual release of MC had occurred per the decision diagram shown in Figure 7.3-1 and Figure 7.3-2, prudent follow-on actions were determined. Potential options considered were additional data collection, including geophysical sampling or hydraulic pumping tests; performance of three-dimensional modeling; or performance of environmental sampling. Environmental sampling was the only option for further assessment of surface water due to the complexity of developing a more detailed surface water model. The best options were determined based on a site-specific basis. Once the further actions had been determined, site-specific plans were developed.

7.3.1 Sampling for MC

MC sampling was conducted when it was determined necessary as the proposed plan of action for further assessment. Prior to conducting the field investigation, a Sampling and Analysis Plan (SAP) / Quality Assurance Project Plan (QAPP) and Health and Safety Plan (HASP) were developed and followed. The SAP/QAPP described the sampling, testing, and quality assurance requirements and procedures while the HASP outlined all appropriate health and safety measures associated with the proposed work.

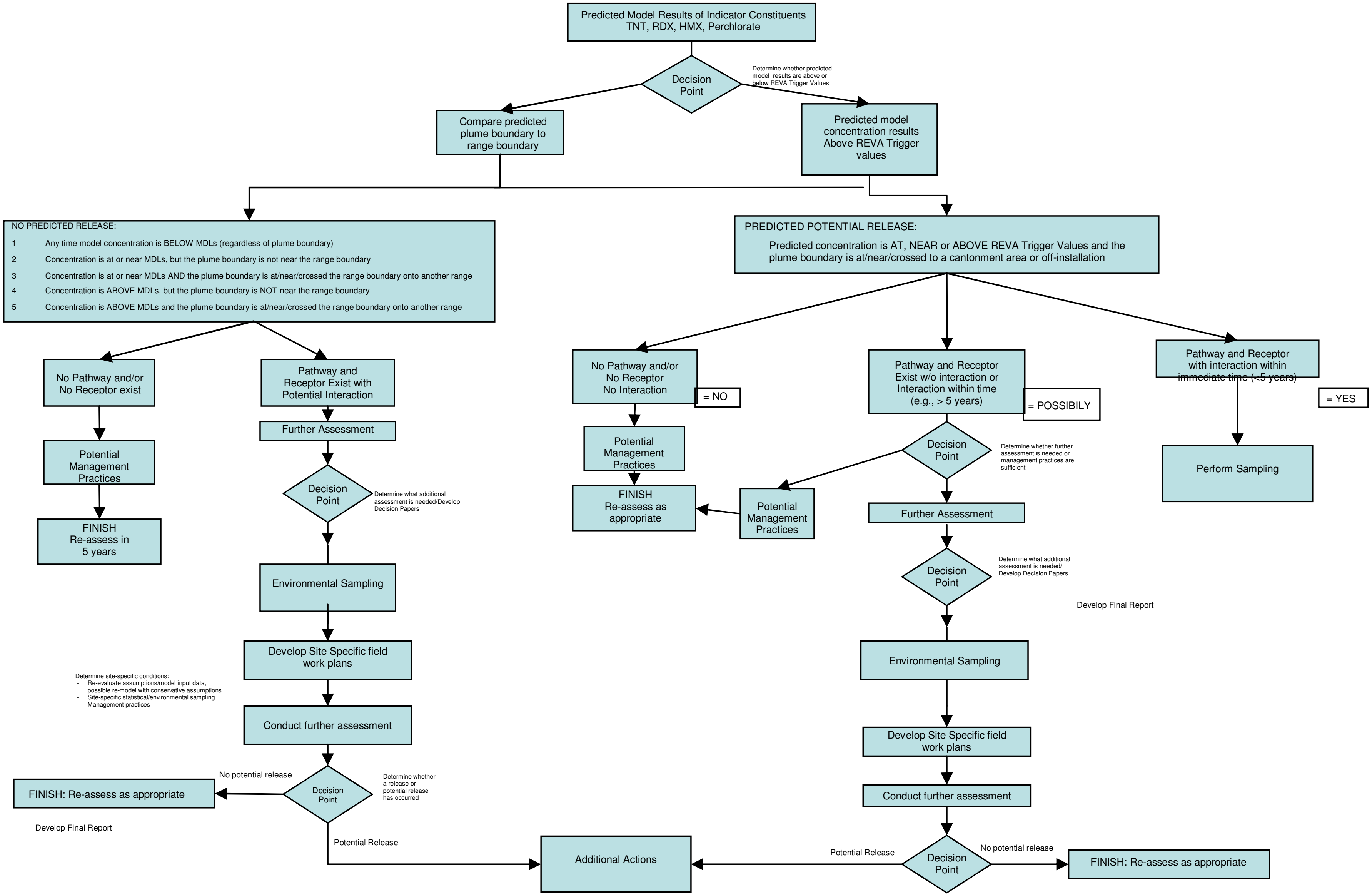


Figure 7.3-1: Decision diagram—from modeling results to next steps

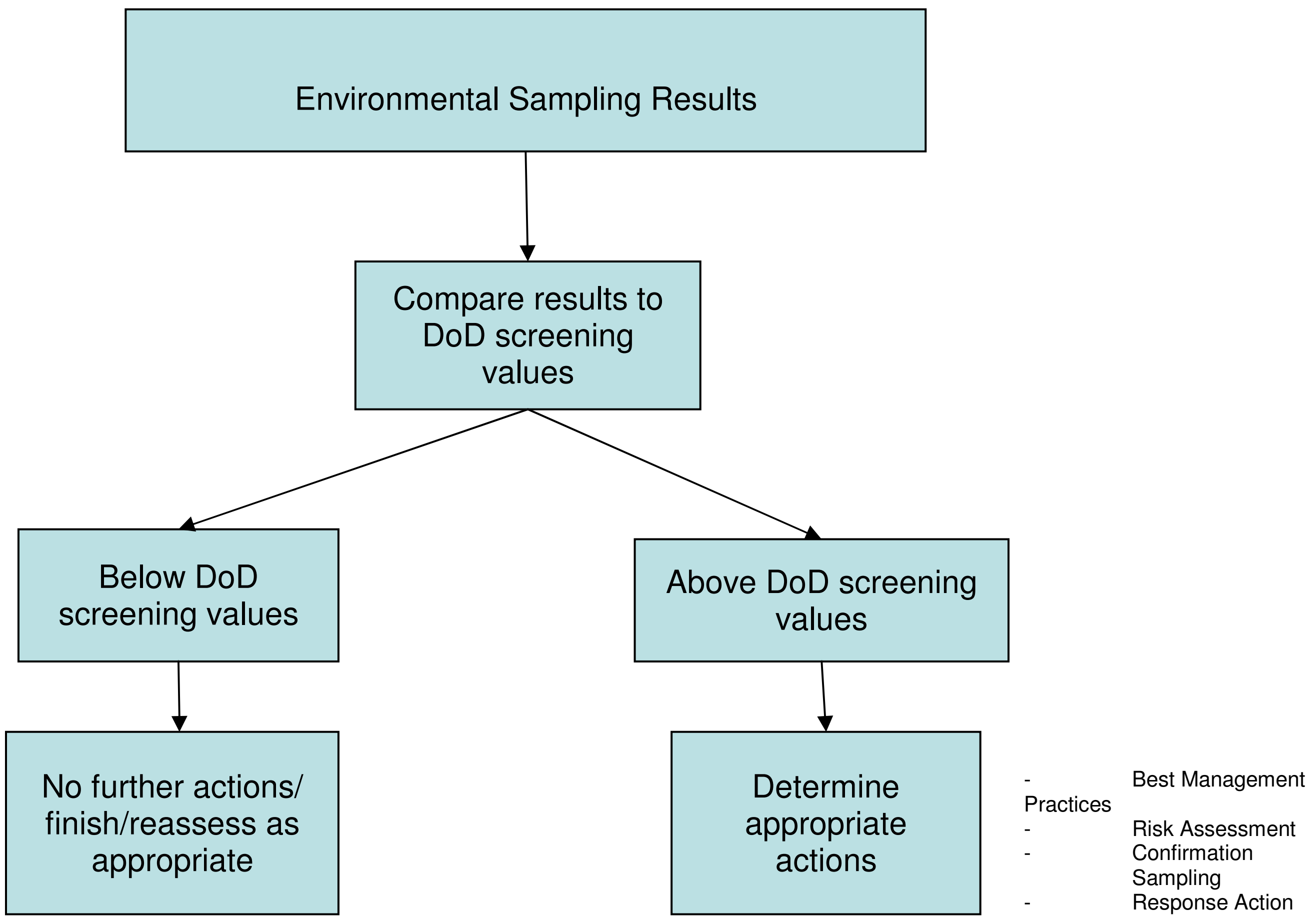


Figure 7.3-2: Sampling results decision diagram

All REVA samples collected were analyzed for the full explosive suite associated with EPA Method 8330 (not just the MC indicator compounds). The sampling results were reviewed against the applicable regulatory standards and DoD threshold guidelines provided in Appendix G to determine whether a response action was necessary. If the sampling results did not indicate that analyzed MC existed within the sampled areas or were below the applicable guidelines, no additional action was necessary. If the sampling results indicated that MC existed above the applicable guidelines, it was determined whether additional actions were warranted. This was not encountered during the baseline assessments.

7.4 CONCLUSION

The baseline assessment was conducted to determine whether a predicted potential for release existed, to identify whether any receptors existed, to identify whether pathways existed from the predicted release to the receptors, and to identify whether there was interaction between the predicted potential release and the receptors. Fate and transport screening-level models were used to identify whether further assessment actions were necessary. Environmental sampling was performed at a few select installations to further determine whether possible MC migration was occurring.

This page left intentionally blank

8.0 PRESENTATION OF REVA RESULTS

Once data collection, extraction, and analysis had been completed and operational range CSMs were created, results were determined and documented (i.e., report). Documented results were made available to the public in accordance with DoDI 4715.14 as a draft final version prior to finalizing after 60 days of release.

The REVA report represented the conditions of the operational ranges at the time the assessments were conducted. The baseline assessment reports for all Marine Corps installations were completed according to the following general template; however, each report was customized according to the installation, as appropriate.

- Section 1 - Introduction
- Section 2 - Summary of Data Collection Effort
- Section 3 - MC Loading Rates and Assumptions
- Section 4 - Groundwater Analysis Method and Assumptions
- Section 5 - Surface Water Analysis Method and Assumptions
- Section 6 - CSM
- Section 7 - Operational Ranges-Training Areas
- Section 8 – SAR Assessment
- Section 9 - References

The contents of these sections are detailed below.

8.1 BASELINE REVA REPORT

The baseline REVA report was created to document the findings and conclusions of the baseline assessment. The Marine Corps provides all draft final baseline assessment reports to identified regulators 60 days prior to report finalization. In addition, HQMC developed REVA Overview and Modeling fact sheets and a REVA Frequently Asked Questions document, which can be provided by range/installation POCs regarding the operational range assessments.

8.1.1 Section 1 - Introduction

The introduction outlines the purpose, scope, and applicability of REVA pertaining to the specific installation. In addition, the introduction outlines the report organization.

8.1.2 Section 2 - Summary of Data Collection Effort

The summary of data collection effort details where and when data were collected for the assessment. This section outlines any external data sources and any data collected from HQMC. In addition, the section details the installation site visit and specific installation offices that were visited and interviewed as part of the data collection process.

8.1.3 Section 3 - MC Loading Rates and Assumptions

As described in Section 4 of this Reference Manual, MC loading calculations were the foundation of the baseline REVA process. The environmental range assessment report documents how the MC loading rates were calculated for the current assessment, including all associated assumptions, and provides a description of the operational range areas associated with the installation. This section also outlines which operational range areas were prioritized for fate and transport screening-level modeling in accordance with Section 6.4

8.1.4 Section 4 - Groundwater Analysis Method and Assumptions

The overall groundwater modeling process is detailed in Section 4 of the report. This section outlines the general groundwater modeling analysis methods, characteristics, and assumptions that were common throughout all the operational ranges at the installation; however, detailed assumptions made specific to an individual operational range are included in the section relating to that operational range. Any special groundwater characteristics, such as low-lying island peninsula areas, are described in this section.

8.1.5 Section 5 - Surface Water Analysis Method and Assumptions

The overall surface water modeling process is detailed in Section 5 of the report. This section outlines the general surface water modeling analysis methods, characteristics, and assumptions that were common throughout the operational ranges at the installation; however, detailed assumptions made specific to an individual operational range are included in the section relating to that operational range. Any special surface water characteristics, such as marsh or upland areas, are described in this section.

8.1.6 Section 6 - CSM

An interim CSM was created as described in this Reference Manual for each operational range being assessed. A revised CSM was the basis for the section pertaining to each operational range within the report. Section 6 outlines the general characteristics of the CSM that are included in each operational range section. In addition, this section details the information sources that were used to create the final CSM that is included in the report. CSM information that is general to all the operational ranges is identified within this section.

8.1.7 Section 7 - Operational Ranges-Training Areas

This section provides an overview of the history and describes each individual operational range / range complex that was modeled and analyzed. The section details the military munitions that were/are used at the operational range and how each operational range is utilized.

The interim CSM became the final CSM once comments/changes had been addressed. The final CSM became part of this section to detail the MC loading calculations and target areas, geography/topography of each operational range, individual surface water features, soil characteristics and land cover, erosion potential, groundwater characteristics, area hydrogeology, potential groundwater and surface water pathways, and potential groundwater and surface water receptors.

The report also details the groundwater analysis results and surface water analysis results for each operational range/area modeled.

8.1.8 Section 8 - SAR Assessment

This section described the process taken during the SAR assessment, details the information used to score Tables 1 through 5 of the SARAP, outlines the scores and evaluation rankings for each SAR assessed, and identifies the additional actions that were taken. This section details whether an identified receptor was or was not expected to be impacted by lead migration through the identified pathway(s). The completed protocol tables for each SAR assessed are included as an appendix to the installation REVA report.

8.1.9 Section 9 - References

All references used to create the baseline environmental range assessment report are documented and presented in this section.

As previously mentioned, the baseline REVA reports generally follow this structure; however, the report was modified for a few installations in order to present the installation's assessment as accurately and clearly as possible.

APPENDIX A

KEY TERMS AND ABBREVIATIONS

KEY TERMS

Code of Federal Regulations (CFR): The compilation of regulations promulgated by EPA and other federal agencies to implement federal laws, including RCRA.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), (*42 USC 9601 et seq.)*: The legislation covering hazardous substance releases into the environment and the cleanup of hazardous substance disposal sites. The regulations are located at 40 CFR 305 and 307.

Data Quality Objectives (DQOs*):* DQOs are statements that define the type, quality, and quantity of data required to answer specific environmental questions and support environmental decision-making.

Detonation [DoD 6055.9-STD, DoD Ammunition and Explosives Safety Standards, August 1997, (A-3)]: As relating to open detonation (OD), detonation is a violent chemical reaction within a chemical compound or mechanical mixture evolving heating and pressure. A detonation which proceeds through the reacted material toward the unreacted at a supersonic velocity. The result of the chemical reaction is exertion of extremely high pressure in the surrounding medium forming a propagating shock wave that originally is of supersonic velocity.

Discarded Military Munitions (DMM) *(10 U.S.C. 2710 (e)(1))*: 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.

Disposal *(40 CFR §260.10*): Process involving the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or waters so that such solid or hazardous waste or any constituent may enter the environment (e.g., burial) or be emitted into the air or discharged into any waters, including ground waters.

Encroachment: Any non-DoD action or constraint that causes or may cause the loss of, or restriction to, the use of land, air, frequency and sea maneuver areas required or planned by Marine Corps to maintain readiness. Encroachment is not limited to the immediate civilian community. Although physical development in conflict with military operations is the most often cited source of encroachment, the actions of more removed entities, such as counties, states, and other federal agencies which determine land use and occupancy, are equal potential sources.

Explosive Ordnance Disposal (EOD): The detection, identification, field evaluation, rendering safe, recovery, and final destruction of UXO or unused munitions as a hazardous material. It may also include the rendering safe or treatment of used or unused munitions.

Hazardous Waste *(40 CFR §261.3)*: In general, a solid waste is a hazardous waste if (1) it is, or contains, a hazardous waste listed in 40 CFR §261 Subpart D or (2) it exhibits characteristics of ignitability, corrosivity, reactivity, and/or toxicity. Refer to 40 CFR §261.3 for further explanation.

Impact Area: An area having designated boundaries within the limits of which all ordnance will detonate or impact.

Military Munitions *(40 CFR §260.10)*: 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, smokes, and incendiaries, including bulk explosives and chemical warfare agents, chemical munitions, rockets, guided missiles, bombs, warheads, mortar rounds, artillery ammunition, small arms ammunition, grenades, mines, torpedoes, depth charges, cluster munitions and dispensers, demolition charges, and devices and components thereof.

Military Range *(40 CFR §266.201)*: A designated land or water area set aside, managed, and used to conduct research on, develop, test, and evaluate military munitions and explosives, other ordnance, or weapon systems, or to train military personnel in their use and handling. Ranges include firing lines and positions, maneuver areas, test pads, detonation pads, impact areas, and buffer zones with restricted access and exclusionary areas. This definition does not include airspace, or water, or land areas underlying airspace used for training, testing, or research and development where military munitions have not been used.

Munitions Constituents *(10 U.S.C. 2710 (e)(4))*: 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.

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).

National Environmental Policy Act (NEPA): This law provides a basic national charter for the protection of the environment. It establishes policy, sets goals, and provides a means for carrying out environmental policy. Environmental Assessments (EAs), Environmental Impact Statements (EISs), and Findings of No Significant Impact (FONSI) are all NEPA documents.

Operational Range *(10 U.S.C. 101(e)(3))*: A range that is under the jurisdiction, custody, or control of the Secretary of Defense and:

(A) that is used for range activities; or

(B) although not currently being used for range activities, that is still considered by the Secretary to be a range and has not been put to a new use that is incompatible with range activities.

Range *(10 U.S.C. 101(c)(3))*: A designated land and water area that is set aside, managed, and used for range activities of the Department of Defense. Such term includes the following:

(A) Firing lines and positions, maneuever areas, firing lanes, test pads, detonation pads, impact areas, electronic scoring sites, buffer zones with restricted access, and exclusionary areas.

(B) Airspace areas designated for military use in accordance with regulations and procedures prescribed by the Administrator of the Federal Aviation Administration.

Resource Conservation and Recovery Act (RCRA): This act regulates the management of solid and hazardous wastes. Specifically, the RCRA requires cradle-to-grave management of all hazardous wastes.

Unexploded Ordnance (UXO) *(40 CFR §266.201)*: 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;

(C) and remains unexploded whether by malfunction, design, or any other cause.

Unused Military Munitions: Unused military munitions include those that have not been fired, dropped, launched, placed, or otherwise used (e.g., munitions in the active inventory available for issue and use in training or operations; munitions issued to a using unit, taken into the field by that unit, but which are not used and which the unit returns to the ASP for return to the inventory).

This page left intentionally blank

ABBREVIATIONS

AEC - Army Environmental Command

AICUZ - Air Installations Compatible Use Zones

ASR - Archive Search Report

ATC - Air Traffic Control

ATSDR - Agency for Toxic Substances and Disease Registry

CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act

CG – Commanding General

CO – Commanding Officer

CPLO - Community Plans and Liaison Office

CRREL - Cold Regions Research and Engineering Laboratory

CSM - Conceptual Site Model

CWA - Clean Water Act

DCM - Data Collection Manual

DMM - Discarded Military Munitions

DoD - Department of Defense

DoDD - Department of Defense Directive

DoDI - Department of Defense Instruction

DoDIC - Department of Defense Identification Code

EAD - Environmental Affairs Department

EO - Executive Order

EOD - Explosive Ordnance Disposal

EPA - Environmental Protection Agency

EPCRA – Employee Planning Community Right-To-Know Act

ERDC - Engineer Research and Development Center

FY - Fiscal Year

GIS - Geographical Information System

GPS - Global Positioning System

HMX - Cyclotetramethylene Tetranitramine

HQMC - Headquarters Marine Corps

ICRMP - Integrated Cultural Resource Management Plan

INFADS - Intranet Navy Facility Asset Data Storage

INRMP - Integrated Natural Resource Management Plan

IRP - Installation Restoration Program

JLUS - Joint Land Use Study

kg - kilograms

m^2 - meters squared

MAP - Modeling Assumptions Package

MC – Munitions Constituent

MCO – Marine Corps Order

MDL - Method Detection Limit

MIDAS – Munitions Items Disposition Action System

NCEA – Non-Combat Expenditure Allowance

NDAA – National Defense Authorization Act

NMFS – National Marine Fisheries Service

NOAA – National Oceanic and Atmospheric Administration

NPDES – National Pollutant Discharge Elimination System

NPL - National Priority List

NREA – Natural Resources Environmental Affairs

OB/OD – Open Burning/Open Detonation

OEESCM – Operational and Environmental Executive Steering Committee for Munitions

OP AREAS – Operating Areas

OP FORCES – Operating Forces

OP TEMPO – Operating Tempo

OSD – Office Secretary of Defense

PAO – Public Affairs Office

PETN - Pentaerythrioletranitrate

PRA – Preliminary Range Assessment

QAPP – Quality Assurance Project Plan

RAICUZ – Range Air Installation Compatible Use Zones

RCMP – Range Comprehensive Management Plan

RCRA – Resource Conservation and Recovery Act

RCUZ – Range Compatible Use Zone

RD – Remedial Design

RDX – Royal Demolition Explosive; Cyclomethylenetrinitramine

REVA – Range Environmental Vulnerability Assessment

RFA – RCRA Facility Assessment

RFMSS – Range Facilities Management Support System

RMUS – Range Munitions Use Subcommittee

SAR – Small Arms Range

SARAP – Small Arms Range Assessment Protocol

SDZ – Surface Danger Zones

SIAD – Sierra Army Depot

SOP – Standard Operating Procedure

SPCC – Spill Prevention Control and Countermeasure

SROC – Senior Readiness Oversight Council

SWP3 – Storm Water Pollution Prevention Plan

T&E – Threatened and Endangered

TECOM – Training and Education Command

TNT – Trinitrotoluene

TRI – Toxics Release Inventory

TRIMS – Target and Range Information Management System

USACE - United States Army Corps of Engineers

USACHPPM – U.S. Army Center for Health Promotion and Preventive Medicine

USFWS – United State Fish and Wildlife Service

UST – Underground Storage Tank

UXO – Unexploded Ordnance

WWTP - Wastewater Treatment Plant

APPENDIX B

REVA FACT SHEETS / FREQUENTLY ASKED QUESTIONS

FACTSHEET

Range Environmental Vulnerability Assessment (REVA) Modeling

Introduction

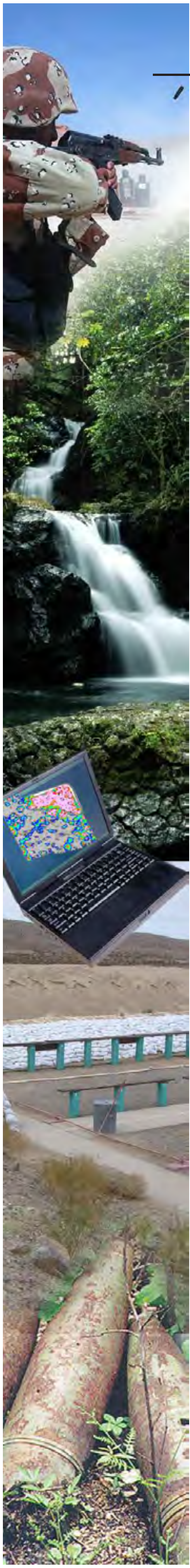
The Marine Corps Range Environmental Vulnerability Assessment (REVA) program includes the use of computer models to evaluate what happens to potential contaminants in surface water and groundwater. These pathways were chosen for evaluation because they are the two primary means in which people and the environment can be exposed to munitions constituents. Scientists regularly use computer models to better understand and evaluate complex environmental systems. REVA uses modeling as a preliminary screening tool to make decisions about whether there is a chance that munitions constituents may be released from an operational range to an off-range area. These screening level models help identify high-priority sites where further investigation is needed as well as locations that are highly unlikely to present environmental issues.

Data Needs

Information required for computer modeling includes operational military munitions use specific to the range being evaluated, as well as environmental data such as soil information, drainage flow patterns, chemical parameters and geology. Both current and historic use of munitions on the ranges has been accounted for in the modeling. REVA uses modeling as a preliminary screening tool at operational range areas that are determined to be the greatest potential of concern. Priorities are developed using data on the estimated amount of munitions constituents loaded on a range over time and whether there are pathways in which these chemicals can get from loading areas to human or sensitive ecological receptors. Based on this analysis, it may not be necessary to model every operational range. In some cases, operational ranges may be grouped together for modeling purposes if they share similar characteristics, including environmental characteristics and/or military munitions use. Other ranges may be screened from the process because their environmental impact can be assessed without computer modeling.

Small arms ranges within REVA are not modeled because site-specific conditions must be known (i.e., geochemical properties) in order to model lead migration. Site-specific geochemical properties are only identified via sampling and cannot be observed physically. Without site-specific physical and chemical characterization, lead cannot effectively be modeled using fate and transport modeling like the other indicator munitions constituents (MC) in REVA. Therefore, lead is assessed through a process designed specifically to determine the potential for lead to become available to the environment and migrate off-range. The factors considered are similar to those in the modeling effort, with the addition of factors relevant to lead release, dissolution, and transport.

The data used in the models comes from a variety of sources. Installations provide environmental studies, reports, and other data on environmental conditions and type, quantity, and frequency of munitions used at each range. The environmental studies and reports may include groundwater investigations, pilot studies, drainage studies, soil and groundwater sampling reports, and other investigations. In addition, outside data sources are researched, such as region water quality control boards, Environmental Protection Agency (EPA), academic institutions, United State Geological Survey, and Natural Resource Conservation Service. The gathered data are used as input to the models to provide a full picture of the area under study.



Surface Water and Groundwater Modeling Approaches

As mentioned above there are two potential contaminant release pathways that are modeled in REVA: groundwater and surface water. These pathways are screened separately following a similar general approach: First the data gathered is combined to create a conceptual site model that describes the pathway at the installation and identifies the data to be used in the modeling. Then the computer models, which are a series of software programs, use mathematical calculations to predict movement of the munitions constituents and potential concentrations in the groundwater or surface water. These results, the model output, are evaluated to assess if there is need for further investigation of the range or if the range does not likely present an environmental problem.

Use of Models to Screen Ranges

The REVA modeling results help decision makers in the REVA process determine whether additional assessment is warranted at a particular range. The modeling results are not intended to be a definitive answer. If the results indicate that there is a potential for munitions constituents to be migrate off-range at detectable levels in surface and/or groundwater and reach human and/or sensitive ecological receptors, then additional investigation (e.g. sampling, risk assessment, etc.) may be warranted.

Selection and Review of REVA Models

All models used in the REVA program are publicly available and approved by the EPA. They also undergo an independent, third-party review of the modeling process and all of the model input parameters. Additional details on the selection and methodology used for the REVA models are provided in Appendix F of the REVA Reference Manual (Former User Guide), which will be located on a publicly available website.

FACTSHEET Range Environmental Vulnerability Assessment (REVA) Overview

Introduction

To effectively carry out its mission, the United States Marine Corps (Marine Corps) must conduct real-time, realistic training involving tactics, procedures, equipment, and personnel on our ranges. The Marine Corps has established a Sustainable Range Program to ensure that training areas are available to future generations of Marines. A key component of the Marine Corps Sustainable Range Program is the Range Environmental Vulnerability Assessment (REVA) program. REVA was developed to help us understand the environmental impacts our range operations may have and identify actions that will keep our ranges operational while protecting human health and the environment. It is a proactive program that supports Marine Corps and Department of Defense goals and policies, but is not required by law or regulation.

REVA is a valuable tool for the Marine Corps because it provides:

- a snapshot of the current environmental conditions of the operational ranges at an installation;
- a detailed assessment of potential munitions constituent (chemical components of munitions) migration from operational ranges;
- valuable information for installation and range managers in formulating strategies for long-term sustainment; and
- early identification of potential environmental issues.

Operational ranges that are addressed under REVA include target/impact areas, firing points, small arms ranges, and training and maneuver areas. REVA also assesses areas with historic munitions use within operational range boundaries.

REVA Process

The REVA process includes data collection, development of a range Conceptual Site Model, groundwater and surface water modeling (if applicable), small arms range assessments, further analysis (e.g., environmental or geophysical sampling, or risk assessment), and documentation of results. REVA establishes an operational range baseline of environmental conditions.

The purpose of the data collection phase is to determine what munitions constituents are present on the range, where they are anticipated to be located, and how they may potentially be moving through the environment. This includes collecting a variety of physical, hydrologic, geographic, and operational data which are used to develop a range Conceptual Site Model. This model outlines or diagrams conditions at the range and identifies if potential pathways and receptors are present that may be potentially impacted by munitions constituents.

The data gathered is used in surface and groundwater models to predict whether any munitions constituents might be migrating from operational ranges and reaching any identified receptors. REVA uses modeling as a preliminary screening tool at operational range areas that are determined to be the greatest potential of concern; which, is determined by munitions loading and complete pathways to receptors. It may not be necessary to model every operational range. In some cases, operational ranges may be grouped together for modeling purposes if they share similar characteristics, including environmental characteristics and/or military munitions use.

FACTSHEET REVA Overview

REVA Process....continued

Other ranges may be screened from the process because their environmental impact can be assessed without computer modeling. Modeling results are used to determine whether further assessment is warranted.

Further assessment may include environmental sampling (e.g., soil, ground water, surface water), characterization of physical properties (e.g., soil properties, hydraulic data), and/or conducting a risk assessment.

Small arms ranges are considered separately from other operational ranges. The REVA process uses a Small Arms Range Assessment Protocol specifically designed to assess the potential for lead to become available to the environment and to migrate off-range where human and ecological receptors may become exposed. The factors considered are similar to those in the modeling effort, with the addition of factors relevant to lead release, dissolution, and transport. The assessment process involves scoring the small arms ranges for each factor, then summing the scores to rank the range as having a low, moderate, or high potential for off-range migration of lead and receptor exposure.

All investigation and small arms range assessment results are documented in a final report upon completion, which will be made available to the public.

Munitions Constituents

The Marine Corps is evaluating the following munitions constituents (MC) as part of their REVA program: trinitrotoluene (TNT), cyclotetramethylene tetranitramine (HMX), hexahydro-trinitro-triazine (RDX), perchlorate, and lead. These MC are considered to be indicator constituents and are the priority chemicals of concern being assessed. Information regarding these MC and any known breakdown by-product chemicals can be found at:

Agency for Toxic Substances & Disease Registry:
http://www.atsdr.cdc.gov/toxpro2.html

Environmental Protection Agency: http://www.epa.gov/IRIS/subst/

U.S. Army Center for Health Promotion and Preventative Medicine:
http://chppm-www.apgea.army.mil/

Navy Environmental Health Center: http://www-nehc.med.navy.mil/main.htm

REVA Schedule

All baseline assessments are anticipated to be complete by the end of fiscal year 2009. Installations will be required to reassess at least every five years.

Where can I get more information?

If you have any more questions or concerns regarding REVA, please contact The REVA Program Manager at 1-703-695-8302.

Frequently Asked Questions. . . cont.

>12 What models are being used for the REVA?

The computer models used for the REVA are a series of software programs. To assess groundwater, the REVA uses unsaturated and saturated zone models to evaluate the area above the groundwater table (i.e., the unsaturated zone) and below the groundwater table (i.e., the saturated zone). A one-dimensional groundwater screening-level model (i.e., VS2DTI) is used to simulate contaminants leaching from the ground surface (i.e., downward movement) through the unsaturated zone. A separate model (Biochlor) is used to simulate horizontal movement of the contaminant in the saturated zone toward the range boundary.

A series of linked calculations are used to estimate munitions constituents' concentrations in surface water runoff from operational ranges. Annual surface water runoff from the site is estimated from precipitation data and land characteristics, and the revised universal soil loss equation is used to estimate soil erosion. A multimedia partitioning model (CalTOX) is used to estimate the distribution of loaded munitions constituents among different environmental media, such as shallow soil, deep soil, and surface water. Simple mixing calculations are used to estimate the reduction in munitions constituents' concentrations expected from the edge of the loading area to downstream locations. More complex surface water transport models are available, if warranted on a case-by-case basis.

All models used in the REVA program are publicly available and approved by the United States Environmental Protection Agency.

>13 What are REVA Trigger Values?

REVA Trigger Values are screening level values to which modeling results are compared to determine whether additional actions are needed. The REVA Trigger Values are based on the median value of compiled method detection limits (MDLs) from various laboratories. The EPA defines an MDL as " the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero." Detection above an MDL simply indicates that the constituent is present in a sample analyzed by the laboratory not that there is an immediate health concern.

>14 When will sampling, if any, take place at an installation?

If the modeling shows a potential for a modeled munitions constituents to migrate off range at concentrations that exceed a conservative, predetermined trigger value, surface water and/or groundwater at an appropriate off-range location will be considered for sampling. Sampling results will be used to determine what further actions, if any, are necessary to reduce or eliminate the potential for munitions constituents to migrate from an operational range.

>15 How are public stakeholders involved in the REVA program?

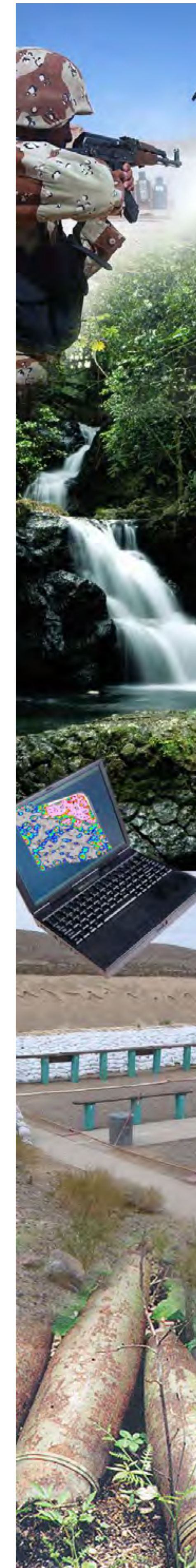
In accordance with DoD guidance as outlined in DoD Instruction 4715.14, the final results of the REVA assessments will be made available to regulatory agencies and the public.

>16 Does this mean that my drinking water might be contaminated by munitions constituents?

No, it does not. REVA is a program to better understand potential long-term impacts of Marine Corps use of its operational ranges. The Marine Corps is proactively assessing the potential for munitions constituents from military munitions use to move off range and for those chemicals to impact human health or the environment. The Marine Corps uses current, as well as historical, data to assist in determining the likelihood that this could happen. At any point in the REVA process, if it is determined that a release of munitions constituents has occurred that potentially impacts human health and/or the environment, an immediate notification will be made to the appropriate regulatory agency (as required by DoD Instruction 4715.14). Working with that agency, the Marine Corps will determine the appropriate response to protect human health and the environment.

>17 Who can be contacted for more information?

For questions regarding the REVA program, please contact the REVA Program Manager at 1-703-695-8302.



FAQ's ?

REVA - Frequently Asked Questions (FAQs)

Questions. . .

- >1 What is a Range Environmental Vulnerability Assessment (REVA)?
- >2 What types of military ranges are being assessed?
- >3 Why are operational range assessments being conducted?
- >4 What regulations govern these assessments?
- >5 What installations are subject to the program?
- >6 What is the schedule for completing the REVA program?
- >7 What munitions constituents are being evaluated?
- >8 What is considered an off-range release?
- >9 What is "munitions constituents loading"?
- >10 What "receptors" are being evaluated?
- >11 How does the REVA assess off-range migration of munitions constituents?
- >12 What models are being used for the REVA?
- >13 What are REVA Trigger Values?
- >14 When will sampling, if any, take place at an installation?
- >15 How are public stakeholders involved in the REVA program?
- >16 Does this mean that my drinking water might be contaminated by munition constituents?
- >17 Who can be contacted for more information?

REVA - Frequently Asked Questions (FAQs)

FAQ's ?

Answers...

>1 What is a Range Environmental Vulnerability Assessment (REVA)?

The REVA is a key component of the Marine Corps Sustainable Range Program. The REVA is a nonregulatory, proactive, and comprehensive approach for environmental sustainability for Marine Corps operational ranges. The purposes of the REVA are to:
Assess whether there might be a release or a substantial threat of a release of munitions constituents of concern, for example 2,4,6-trinitrotoluene (TNT), 1,3,5-trinitro-1,3,5-triazine or Royal Demolition eXplosive (RDX), High Melting eXplosive (HMX), perchlorate or lead from an operational range to an off-range area;
Enhance the Marine Corps' ability to prevent or respond to a release or substantial threat of a release of munitions constituents of concern from an operational range to an off-range area; and Enhance the Marine Corps' situational awareness of the environmental conditions of operational range and training area resources.

>2 What types of military ranges are being assessed?

Only operational ranges are being assessed under this program. An operational range is defined in Title 10 of the United States Code Section 101(d)(3)(A) and (B) as " a range that is under the jurisdiction, custody, or control of the Secretary of Defense and that is used for range activities or, although not currently being used for range activities, that is still considered by the Secretary to be a range and has not been put to a new use that is incompatible with range activities." Types of range areas assessed include target/impact areas, firing points, small arms ranges and other training and maneuver areas using military munitions. Areas that are excluded from the assessment include indoor ranges, recreational use ranges, ranges no longer used for operational purposes, and ranges covered by a Resource Conservation Recovery Act Subpart X permit.

>3 Why are operational range assessments being conducted?

In an effort to better understand the long-term impacts of the use of its training lands, the Department of Defense (DoD) proactively implemented DoD Instruction 4715.14 Operational Range Assessments. This DoD Instruction established requirements for the military services to conduct assessments on all operational ranges in the United States. The Marine Corps has implemented the REVA program to improve its environmental stewardship program, to meet the requirements of the DoD Instruction, and to address environmental concerns proactively so that they do not lead to training restrictions.

>4 What regulations govern these assessments?

Currently, no regulations require these operational range assessments. However, the DoD is taking a proactive approach to its stewardship responsibilities. It has implemented both the DoD Directive 4715.11 Environmental and Explosives Safety Management on Operational Ranges within the United States and DoD Instruction 4715.14 Operational Range Assessments to ensure that range operations are not harming or creating an unacceptable risk to human health and/or the environment. DoD Directive 4715.11 requires Marine Corps installations to maintain an inventory of their operational ranges and to evaluate the potential for off-range migration of munitions constituents. DoD Instruction 4715.14 lays out a scientifically sound process for assessing and reporting potential off-range environmental impacts of military munitions used on operational ranges.

>5 What installations are subject to the program?

REVAs will be conducted at all Marine Corps installations in the United States that have operational ranges:

Marine Corps Air Station Cherry Point, North Carolina
Marine Corps Base Camp Lejeune, North Carolina
Marine Corps Base Camp Pendleton, California
Marine Corps Recruit Depot Parris Island, South Carolina
Marine Corps Air Station Beaufort, South Carolina
Marine Corps Air-Ground Combat Center Twentynine Palms, California
Marine Corps Base Quantico, Virginia
Marine Corps Mountain Warfare Training Center Bridgeport, California
Marine Corps Air Station Yuma / Chocolate Mountains and Bob Stump Range, Arizona
Marine Corps Logistics Base Barstow, California
Marine Corps Logistics Base Albany, Georgia
Marine Corps Air Station Miramar, California

>6 What is the schedule for completing the REVA program?

The REVA assessments are scheduled to be completed by the end of September 2008. Follow on work, to include the completion of REVA reports at certain installations will be completed in 2009.

>7 What munitions constituents are being evaluated?

For the purposes of the REVA program, indicator munitions constituents specifically identified for assessment include TNT, RDX, HMX, perchlorate, and lead. These munitions constituents are considered to be indicator constituents for the following reasons:
Numerous studies conducted on military installations on the frequency of occurrence of specific munitions constituents in soil and groundwater have shown that TNT or RDX have been detected in a high percentage of analyzed samples.
Studies have also shown that RDX and perchlorate are mobile within the environment and have the highest potential to migrate off range.
TNT, RDX, and HMX do not degrade rapidly and persist in the environment for long periods of time.
Lead is a commonly identified metal associated with small arms ammunition used by the military.

>8 What is considered an off-range release?

Off-range areas include those areas outside the boundaries of an operational range or operational range complex. Off-range areas can be outside an installation boundary or on installation property but outside of an operational range (e.g., cantonment area). An off-range release is the migration of munitions constituents beyond the defined operational range boundary via a transport mechanism (e.g., surface water runoff, groundwater flow). Munitions constituents migration into an on-range drinking water supply well would also be considered a release.

>9 What is "munitions constituents loading"?

" Munitions constituents loading" is the term used in the REVA program to describe the amount and types of munitions constituents potentially deposited onto the operational ranges as a result of military munitions training activities. The amount and types of munitions constituents fired onto the operational ranges must be estimated for use in computer models that assess the potential for munitions constituents to migrate off range at detectable concentrations. Where available, expenditure data will be used. See also Question #11.

>10 What "receptors" are being evaluated?

REVA evaluates both human and ecological receptors that could be exposed to munitions constituents if the constituents migrate off range. The identification of potential human and ecological receptors at an installation is an important step in the REVA process.

>11 How does the REVA assess off-range migration of munitions constituents?

The REVA process uses computer models to assess the potential for munitions constituents to migrate off range to potential receptors through groundwater and surface water pathways. Data for the modeling effort are collected from existing reports and databases; site-specific information is used whenever it is available. The REVA process uses reasonable and conservative assumptions when selecting inputs to the models. Modeling results are used to evaluate if further action might be necessary, including best management practices or field sampling.

Small arms ranges are considered separately from other operational ranges. The REVA process uses a Small Arms Range Assessment Protocol specifically designed to assess the potential for lead to migrate off range. Various factors related to lead release, dissolution, and transport are considered. The assessment process involves scoring a small arms range for each factor, then summing the scores to rank the range as having a low, moderate, or high potential for off-range migration of lead and receptor exposure.

The REVA team, an outside third party, and the installation carefully review these modeling efforts and small arms range assessments. All investigation results are documented upon completion.

APPENDIX C

SMALL ARMS RANGE ASSESSMENT PROTOCOL

SMALL ARMS RANGE ASSESSMENT

Introduction

The purpose of the Range Environmental Vulnerability Assessment (REVA) is to identify whether there has been a release or there is a substantial threat of a release of munitions constituents (MC) of concern from the operational range or range complex areas to off-range areas. This is accomplished through the use of fate and transport modeling and analysis of the REVA indicator MC based upon site-specific environmental conditions at the operational ranges and training areas at an installation.

MC associated with small arms ammunition commonly used at operational ranges includes lead, antimony, copper, and zinc. REVA focuses on lead as the MC indicator for small arms ranges because lead is the most prevalent (by weight) potentially hazardous constituent associated with small arms ammunition. No specific quantitative conclusions can be made regarding the fate and transport of lead since it is unlike any other MC. Lead is geochemically specific regarding its mobility in the environment. Site-specific conditions must be known (i.e., geochemical properties) in order to quantitatively assess lead migration. Site-specific geochemical properties are only identified via sampling and cannot be observed physically. Without site-specific physical and chemical characterization, lead cannot effectively be modeled using fate and transport modeling like the other indicator MC in REVA. The scientific community has established that metallic lead (such as recently fired, unweathered bullets and shot) generally has low chemical reactivity and low solubility in water and is relatively inactive in the environment under most ambient or everyday conditions. However, a portion of lead deposited on a range may become environmentally active if the right combination of conditions exists.

For small arms ranges, the fate and transport parameters are based entirely on site-specific geochemical properties, which cannot be determined solely by physical observation. Therefore, small arms ranges associated with the installation are qualitatively reviewed and assessed to identify factors that influence the potential for lead migration at the operational range, including:

- design and layout,
- the physical and chemical characteristics of the area, and

- current and past operation and maintenance practices.

In addition, potential receptors and pathways must be identified relative to the small arms range being assessed. The potential for an identified receptor to be impacted by MC migration through an identified pathway will be evaluated.

This Small Arms Range Assessment Protocol was developed in lieu of collecting site-specific information for every small arms range. The protocol will help to determine which ranges necessitate data collection of site-specific geochemical properties or further assessment based the range's overall prioritization regarding the potential for an identified receptor to be impacted by potential lead migration through an identified pathway.

Purpose

This Small Arms Range Assessment Protocol outlines a qualitative approach to assess the small arms ranges in the REVA process in lieu of collecting site-specific geochemical properties at every range. This qualitative approach helps to identify and assess factors that influence the potential for lead to migrate at an operational range.

This protocol is to be used for:

1) Identifying the small arms ranges within the Marine Corps that have the greatest potential for environmental concern (i.e., potential for lead migration to impact identified receptors) and
2) Assessing the need for implementing further actions. Recommended further actions may include, but are not limited to, the following:
   - Sampling surface water, groundwater, and/or soil
   - Conducting additional studies
   - Implementing best management practices (BMPs)

Data Collection and Documentation

The qualitative assessment process for a small arms range involves first capturing and documenting its physical and environmental conditions, as well as how the range is utilized and maintained (including dates of use and types and amounts of small arms ammunition expended). The small arms range data collection form within Section 3 of the REVA Reference Manual is a guide to collecting and documenting the necessary information in order to complete the evaluation forms presented later in this protocol (Tables 1 through 6). It includes a comprehensive list of data elements that are useful in establishing the historical and current physical and environmental conditions, as well as capturing the types of information on conditions that influence lead's potential to migrate from the range. The data collection form is organized by major topics or information areas associated with the operational range, including the following:

- Basic range information
- Current range layout
- Current range operations
- Historical range operations
- Amount of lead potentially deposited
- Environmental Characteristics
- Potential receptors
- Surrounding land use
- Environmental activities conducted on the range
- Summary

The data collection form in the REVA Reference Manual can be modified, where needed, to fully capture the major factors that can potentially influence lead's ability to migrate from each specific small arms range.

Qualitative Assessment

The small arms range can be qualitatively assessed once the conditions of the range have been fully understood and documented. The assessment process involves a discussion of possible factors that can influence the potential for lead to migrate off range. Several of these factors are listed below, followed by a detailed discussion:

- Range use and range management (source)
- Surface water
- Groundwater and soil
- Pathways

- Receptors

Range Use and Range Management (Source)

The amount of lead and other MC deposited on a range is a combination of the following factors:

- Duration of use
- Current and historical frequency of range usage
- Amount and types of small arms ammunition expended on the range
- Scope and frequency of any range maintenance activities involving the removal of lead from the range
- Presence and duration of bullet-capturing technologies

Surface Water

Under specific pH conditions, lead from shot or bullets can slowly dissolve in water. Runoff and groundwater discharge could transport this dissolved lead off range. The primary factors influencing the potential for dissolved lead to migrate via surface water include, but are not limited to, the following:

- pH of the water
- Duration of water contact with the lead
- Intensity and frequency of rainfall
- Steepness of the slope containing lead
- Amount and type of vegetation on the slope
- Infiltration rate of surface soils
- Presence of engineering controls or BMPs to modify or control surface water runoff

Groundwater and Soil

The amount of lead that dissolves in water is primarily influenced by the pH of the water and the duration of water contact with the lead. Once lead is dissolved in water, the amount of lead that attaches to the soil and/or enters the groundwater is determined by several factors, including the following:

- Organic carbon content of the soil
- pH of the soil

- Properties of the soil, including porosity, irreducible water content, and hydraulic conductivity
- Amount of recharge percolating through the vadose zone
- Clay content of the soil (lead attaches to clay minerals more than other soil fractions)
- Depth to groundwater

Pathways

The REVA Small Arms Range Assessment involves developing a conceptual site model (CSM) for the range to identify the range's physical and environmental conditions. The CSM's purpose is to identify if a potential for source-receptor-pathway interaction may exist. Factors that influence the potential for a source-receptor-pathway interaction (e.g., heavy range use, potable water supply wells in proximity to the range), as well as factors that decrease the potential for such interactions, should be discussed in the assessment.

Potential pathways include:

- groundwater used as a source of potable or agricultural water,
- the use of surface water downstream of a range as a source of potable or agricultural water, and
- the use of the soil, surface water, or groundwater by sensitive species.

Receptors

Receptors in REVA can include on-range and off-range personnel and sensitive species and ecosystem areas. Factors considered when assessing the potential complete exposure pathways to receptors include, but are not limited to, the following:

- The number and proximity of water supply wells relative to the range
- The characteristics of nearby water supply wells (e.g., depth to groundwater, well construction details)
- The uses of the surface water or groundwater (e.g., agriculture, drinking water)
- The locations of nearby sensitive species areas, such as endangered species habitats (i.e., within proximity to the range)

Small Arms Range Assessment Protocol

This Small Arms Range Assessment Protocol is based on evaluating the potential environmental concerns posed by MC. Environmental concern evaluation rankings for surface water and groundwater conditions are established for each small arms range. The rankings range between High (indicating the highest potential environmental concern) and Minimal (indicating the lowest potential environmental concern). Possible recommended actions are based on the relative environmental concern evaluation rankings assigned by the protocol. High rankings necessitate further actions. Further actions may include sampling, additional site-specific studies, and/or BMPs. These actions will be evaluated based on site specific conditions for each range.

Protocol Instructions

1. For Tables 1 through 5:
   a. Enter the appropriate score for each criteria in the site score column. Use the highest (i.e., most conservative) value if no information is known to complete the score. Professional judgment may be used at any time to override a designated score. If professional judgment is used, mark the score column appropriately (*) and fill in the notes section at the bottom of the table with text detailing why professional judgment was used and how it impacted the scores.
   b. Sum the site scores in the last row.
2. Transfer the scores from Tables 1 through 5 onto Table 6 in the appropriate rows.
3. Use the scores in Table 6 to determine the surface water and groundwater environmental concern evaluation rankings.

Evaluation Ranking Designation

Once Table 6 is complete, the protocol finishes with two scores: the sum of surface water elements and the sum of groundwater elements. These scores are used to identify the appropriate evaluation ranking (High, Moderate, Minimal) for surface water and groundwater (as mentioned in step 3 of the protocol instructions).

The surface water concern evaluation ranking and the groundwater concern evaluation ranking identify the potential impact for lead migration for each of those pathways at the small arms range. The ranking designations and their descriptions follow:

- High = Small arms range most likely has the potential for lead migration creating the greatest level of environmental concern and requiring additional action(s).

- Moderate = Small arms range may have the potential for lead migration and most likely indicating that there is no immediate environmental concern, but actions may be necessary to prevent a greater concern.
- Minimal = Small arms range has minimal or no potential for lead migration indicating minimal threat of environmental concern, but actions may be necessary to ensure that the no concerns elevate.

These rankings are used to determine whether additional actions are appropriate. The highest environmental concern evaluation ranking (surface water or groundwater), as determined in Table 6, is used to evaluate if further actions are suggested, based on the guidelines for recommended actions (Table 7).

The overall range evaluation rankings should be compared to each range within the installation and to the overall rankings of all ranges across the Marine Corps. These rankings will assist in determining how funding should best be allocated across the Marine Corps to prevent environmental concerns due to small arms ranges.

Assessment Report

Once the Small Arms Range Assessment Protocol has been completed and appropriate actions have been designated and implemented, the assessment should be written into a report that describes the process taken, details the information used to score Tables 1 through 5, outlines the scores and evaluation rankings, and identifies the additional actions taken. The report should detail whether an identified receptor is or is not impacted by lead migration through the identified pathway(s). The completed protocol tables should be included as an appendix to the report.

Best Management Practices for Small Arms Ranges

BMPs are important for all ranges and should be used appropriately to maintain the sustainability of operational ranges. However, this protocol prioritizes which small arms ranges may need BMPs to address specific possibilities of lead migration.

Following the Small Arms Range Assessment, BMPs may be recommended based on the environmental concern evaluation ranking. Prior to selecting and implementing BMPs, the management objectives must be established. Depending on the range-specific site conditions and the management objectives, the following BMPs should be considered:

- Bullet and shot containment techniques (e.g., berms, backstops, traps)
- Prevention of soil erosion from berms, aprons, and other range areas
- Soil amendments
- Recovery and/or recycling of lead

Negative impacts of implementation should also be considered when selecting a BMP. For example, using soil amendments may affect water quality of nearby water bodies or modifying surface water runoff may impact nearby habitats.

The prevention of soil erosion can be achieved by implementing one or several of the following practices:

- Maintaining vegetation on berms and drainageways
- Reducing runoff rates by adjusting site drainage patterns
- Providing sediment traps such as a vegetated detention basin or infiltration area
- Preventing the creation of a "point source"

Soil amendments may be an effective BMP by implementing one or both of the following practices:

- Increasing the retentive capacity of soil by adding organic matter, fertilizer, and/or lime
- Maintaining a pH range between 6 and 8 by adding triple superphosphate, bone meal, or other applicable additives

The recovery and recycling of lead from operational ranges should be considered as a way to control the migration of lead. The following should be considered when implementing recovery and recycling practices:

- Focus on safety as the primary concern of the proposed activities
- Avoid practices that appear as treatment activities (e.g. acid leaching, fixation, etc.)
- Dispose lead by using a lead recycler or smelter
- Use residual soil for the original purpose (e.g. berm/target area soil) following lead recovery practices.

TABLES

Small Arms Range Protocol Evaluation Forms

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	Evaluation Characteristics	Score Criteria	Site Score
Duration of Range Use	Length of time the range has been used	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	
Bullet-Capturing Technology	The presence and duration of bullet-capturing technologies Compare the duration of the range use to the duration of bullet-capturing technologies.	If [range usage duration = bullet capture duration], then apply a **negative** score so that the [range usage duration + bullet capture duration] = 1 If [range usage duration – bullet capture duration] = 10 to 30 years, then apply a **negative** score so that the [range use duration + bullet capture duration] = 3 0 if [range usage duration – bullet capture duration] > 30 years	
MC Loading Rates	The amount and types of small arms ammunition expended on the range Estimate the MC loading by using a time weighted average of MC loading rates	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	
Range Maintenance	Frequency of any range maintenance activities involving the removal of lead from the ranges	5 if lead is removed less than every three years 3 if lead is removed more than every three years but less than annually 1 if lead is removed at least annually	
Source Element Score			
Notes:			

Small Arms Range Protocol Evaluation Forms

Table 2: Surface Water Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	Evaluation Characteristics	Score Criteria	Site Score
pH of Water	pH below 6.5 increases the rate of lead dissolution.	5 if pH < 6.5 1 if pH ≥6.5	
Precipitation	Intensity and frequency of precipitation	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	
Slope of Range	The amount of deviation from the horizontal for the berm / target area	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	
Vegetation	Approximate vegetation cover within and directly downslope of the surface danger zone	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	
Soil Type/Runoff Conditions	Soil with a higher porosity (sands/gravels) has more infiltration and less runoff compared to soil with low porosity (silts/clays).	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	
Runoff/ Erosion Engineering Controls	The presence of engineering controls or BMPs to modify or control surface water runoff and erosion Partial engineering controls include using erosion controls such as a proper groundcover or use of berms or backstops. Using a combination of multiple partial engineering controls may create an effective engineering control. Other effective engineering controls include bullet containment technologies.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	
Surface Water Pathway Score			
Notes:			

Small Arms Range Protocol Evaluation Forms

Table 3: Groundwater Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Characteristics**	**Score Criteria**	**Site Score**
Depth to Groundwater	The potential for impact to the groundwater decreases with an increasing depth to the water table.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater >300 feet	
Precipitation	Intensity and frequency of precipitation	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	
pH of Water	pH below 6.5 increases the rate of lead dissolution.	5 if pH < 6.5 1 if pH ≥ 6.5	
pH of Soil	Lead tends to stay dissolved at pH conditions less than 6.5 and tends to attach to soil particles at pH conditions above 8.5.	5 if pH < 6.5 3 if pH > 8. 1 if 6.5 ≤ pH ≤ 8.5	
Soil Type/Infiltration Conditions	Soil with a higher porosity (sands/gravels) has more infiltration and less runoff compared to soil with low porosity (silts/clays).	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	
Clay Content in Soil	Amount of clay in the soil Lead attaches to clay soil more readily than any other soil types.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	
Groundwater Pathway Score			
Notes:			

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	Evaluation Characteristics	Score Criteria	Site Score
Drinking Water Usage	Identify if nearby surface water bodies are used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	
Agricultural or Other Beneficial Usage	Identify if nearby surface water bodies are used as an agricultural or other beneficial use, such as recreational (excluding drinking water).	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	
Sensitive Species Habitat and Threatened or Endangered Species	Identify if nearby surface water bodies are downgradient of or nearby any sensitive species habitat or threatened or endangered species.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	
Surface Water Receptor Score			
Notes:			

Small Arms Range Protocol Evaluation Forms

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	Evaluation Characteristics	Score Criteria	Site Score
Wells Identified as Potable Water Sources	Number and location of potable water or potable water supply wells relative to the location of the range Evaluate well construction / radius of influence data and hydrogeologic setting to assess if wells are potential receptors.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	
Wells Identified for Agricultural or Other Beneficial Usage	Number and location of agricultural wells relative to the location of the range Evaluate well construction / radius of influence data and hydrogeologic setting to assess if wells are potential receptors.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but iare not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	
Sensitive Species Habitat and Threatened and Endangered Species	Evaluate of groundwater discharge or usage near areas of sensitive species habitat or areas where threatened and endangered species are located within proximity of the range	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	
Groundwater Receptor Score			
Notes:			

Small Arms Range Protocol Evaluation Forms

Table 6: Relative Environmental Concern Evaluation (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	
Surface Water Pathways	2	
Surface Water Receptors	4	
Sum of Surface Water Element Scores		
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	
Groundwater Pathways	3	
Groundwater Receptors	5	
Sum of Groundwater Element Scores		

The relative environmental concern evaluation ranking for each media is determined by selecting the appropriate score based on the data elements for that media:

Environmental Concern Evaluation Ranking*	Score Range
High	50-65
Moderate	30-49
Minimal	0-29

*Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.

Surface Water Environmental Concern Evaluation Ranking	
Groundwater Environmental Concern Evaluation Ranking	
Notes:	

Table 7: Guidelines for Recommended Actions	
Environmental Concern Evaluation Ranking	Recommended Action
High	Action required. 1) Sample appropriate media (groundwater, surface water, and/or soil). 2) Identify and Implement BMPs.
Moderate	1) Consider identifying and implementing BMPs, as appropriate. 2) Consider sampling appropriate media (groundwater, surface water, and/or soil).
Minimal	1) No further action needed, at this time. 2) Consider identifying and implementing BMPs, as appropriate.

APPENDIX D

REVA MC LOADING CALCULATOR DETAILS AND DEVELOPMENT

REVA MC LOADING CALCULATOR DEVELOPMENT

Each MC loading area identified within REVA requires a MC loading rate be calculated in order to perform the modeling; therefore, the MC Loading Calculator was developed. For the purposes of REVA, the MC loading estimates are determined as average concentrations (kg/m^2) deposited annually in the MC loading area for the duration that the range activities generating the MC loading were conducted. Each of the assumptions associated with the determination of a loading rate, as well as the calculator parameters used, are documented in the REVA report for the respective installations.

The mass-loading principles discussed in Section 4.2.3 Estimating MC Loading were observed in order to more accurately quantify the MC potentially deposited as a result of low order detonations, high order detonations, and duds. Dud rate and low order rate data are estimated based upon the July 2000 study done by the U.S. Army Technical Center for Explosives Safety *Report of Finding for Study of Ammunition Dud and Low Order Detonation Rates.* Dud and low order rates are tracked, reported and made available according to DoDIC. For the DoDICs that dud or low order rates are not available, default values of 3.45% (dud rate) and 0.028% (low order rate) are used. In addition, the amount of residual explosives remaining after a low-order detonation, and a high order detonation are estimated to be 50% and 0.1%, respectfully.

The primary source for MC data is DAC's MIDAS website. In addition to MIDAS, other sources used for MC data included the ORDDATA II software and various ordnance technical manuals. These sources provided the types and amounts of energetic fillers associated with the military munitions known or suspected to have been used at the range. In cases where specific munitions use data are unavailable, the military munitions types selected were based upon common military munitions used during the active time periods of the operational range. Perchlorate data are obtained from an analysis of perchlorate containing military munitions, which can be obtained from various technical manuals or other electronic database systems such as MIDAS (https://midas.dac.army.mil/). The Marine Corps authorized allowances, with a few minor exceptions, are similar to the Army.

TRAINING FACTOR

Historically, military training operations have been affected by campaigns and wars over time. This affect usually resulted in an increase in training prior to a conflict and tapering off during it, with training increasing again toward the end of the conflict and then subsequently decreasing again to a non-war level. REVA attempted to account for this training affect by developing a training timeline of significant events beginning in 1914 through today. This timeline accounts for the following events:

- World War I
- World War II
- The Cold War
- The Korean War
- The Vietnam Conflict
- The Persian Gulf
- Afghanistan, and
- Iraq

The results of the training analysis resulted in the development of four periods that increase the loading rate for that period by a Training Factor, as well as a baseline[1] level of training. The periods identified and their associated Training Factors are as follows:

- Period A: 1914-1924 (Baseline + 40%)
- Period B: 1925-1937 (Baseline)
- Period C: 1938-1976 (Baseline + 50%)
- Period D: 1977-1988 (Baseline + 20%)
- Period E: 1989-Present (Baseline + 50%)

The baseline expenditure rate is applied to each year the area of interest or range was in use. The MC Loading Calculator automatically applies the training factor adjustments according to the time period so that loading rates are estimated for each year the range was known or suspected to be in use. All known data and assumptions input into the MC Loading Rate Calculator for each operational range area being assessed are documented in the individual REVA reports.

Using the Calculator

In its simplest application, the Calculator initially requires completion of the MC spreadsheets. This entails entry of the following data points:

- Description of the military munitions used within a MC loading area (Column F: Documented Munition DoDIC or Nomenclature)
- Quantity of military munitions used (Column L: Total Ordnance Quantity for Baseline)
- Matching the munitions description to an item in the DoDIC picklist (Column G: Picklist DoDIC Match).
- Area of the MC loading area (Column AC: Affected Target Surface Area)
- Years of the respective time periods (Periods A, B, C, D, and/or E) that the MC loading area was operational (Columns AI, AO, AU, BA, and BG: Duration)

Once this information has been entered, the Calculator references the munition worksheet to retrieve MC, dud, low order, and high order data and calculates the Total Average Load Rate for each MC loading area, by period. The following figure demonstrates the calculation of the load rate for a MC loading area for RDX during Period C.

Calculations where less information is available can be made using additional columns that attempt to account for the type of weapon system being used, number of weapon systems, number of military munitions per weapon system, and etcetera.

---

[1] Training model assumes a 20-60-100% increases for years leading up to war (Vietnam training increases stretched over longer periods), with only a 60-40% percent increase during two years after war, maintaining at 40% during war, and a 60-80% increase beginning at end of war followed by a 60-40-20-return to non-war (baseline) level. This is modeled for each war, with the highest modeled level taking precedence when determining what level of training occurred during overlapping timeframes. Assume cold war had only a 20% increase over its life.

Munitions Worksheet

DODIC	Nomenclature	DUD (%)	Low Order Dets (%)	High Order Dets (%)	EXPLOSIVES (lbs) Low RDX	High RDX	Average RDX
H929	WHD, SMK PWP MK34 MOD 0 F/5 IN RCKT	3.45	0.02800	96.52	0.000000	0.000000	0.000000
H930	WHD, HE MK24 MOD 0 F/5 IN RCKT	3.45	0.02800	96.52	5.460000	5.460000	5.460000
H931	WHD HE MK32 MOD0 F/5IN RCKT	3.45	0.02800	96.52	9.044700	9.044700	9.044700
HA06	WHD, FLARE 2.75 IN RCKT M278	3.45	0.02800	96.52	0.000000	0.000000	0.000000

MC Worksheet data reference row for DoDIC H930

Munition description gathered from range expenditure source (i.e., range control, ASR, PRA, etc.

Picklist item match

Data Automatically Pulled from Munitions Worksheet

Data Automatically Pulled from Munitions Worksheet

Data Automatically Pulled from Munitions Worksheet

Data Automatically Pulled from Munitions Worksheet (Converted to Kg)

Size of MC loading area (M^2)

Training Factor

Length of use during Period C

MC Worksheet (RDX)

F	G	L	O	Q	S	T	V	W	Y	Z	AB	AC	AD	AT	AU	AV	AW	AX
														Period C (1938-1976)				
Documented Munition DoDIC or Nomen.	Picklist DoDIC Match	Total Ordnance Quantity for Baseline	REVA MC Weight (Kg)	Percent DUD Estimate	DUD Analyte Cont. (Kg)	Percent Low Order Estimate	Low Order Analyte Cont. (Kg)	Percent High Order Estimate	High Order Analyte Cont. (Kg)	Total Potential Surface Analyte Cont. (Kg)	Total Potential Surface Analyte Available at Target (Kg)	Affected Target Surface Area (m^2)	Surface Soil Baseline Annual Load Rate (Kg/m^2)	Training Factor	Duration	Surface Load Rate (Kg/m^2)	Soil Conc. (Kg/m^3)	Average Annual Surface Load Rate (Kg/m^2)
Whd, 5", MK 28 HE	H930	27	2.48E+00	3.450000	2.31E-02	0.028000	9.36E-03	96.522	6.45E-02	9.70E-02	9.70E-02	2.21E+04	4.38E-06	1.50	27	1.77E-04	3.88E-04	6.57E-06
Whd, 5", MK 32 HEAT	H931	19	4.10E+00	3.450000	2.69E-02	0.028000	1.09E-02	96.522	7.52E-02	1.13E-01	1.13E-01	2.21E+04	5.10E-06	1.50	27	2.07E-04	4.53E-04	7.66E-06
Whd, 5", MK 34, AP/ASW	H929	2	0.00E+00	3.450000	0.00E+00	0.028000	0.00E+00	96.522	0.00E+00	0.00E+00	0.00E+00	2.21E+04	0.00E+00	1.50	27	0.00E+00	0.00E+00	0.00E+00
Whd, 5", MK 36, PWP	H929	2	0.00E+00	3.450000	0.00E+00	0.028000	0.00E+00	96.522	0.00E+00	0.00E+00	0.00E+00	2.21E+04	0.00E+00	1.50	27	0.00E+00	0.00E+00	0.00E+00
Rocket Motor, 5"	H311	100	0.00E+00	3.450000	0.00E+00	0.028000	0.00E+00	96.522	0.00E+00	0.00E+00	0.00E+00	2.21E+04	0.00E+00	1.50	27	0.00E+00	0.00E+00	0.00E+00
Whd, 2.75", MK 6, HE	H842	316	6.40E-01	3.450000	6.98E-02	0.028000	2.83E-02	96.522	1.95E-01	2.93E-01	2.93E-01	2.21E+04	1.32E-05	1.50	27	5.36E-04	1.17E-03	1.99E-05
Whd, 2.75", MK 7, HEAT	2.75" HEAT	117	2.53E-01	3.450000	1.02E-02	0.028000	4.14E-03	96.522	2.85E-02	4.28E-02	4.28E-02	2.21E+04	1.93E-06	1.50	27	7.83E-05	1.72E-04	2.90E-06
Whd, 2.75" (inert warhead)	INERT	400	0.00E+00	0.000000	0.00E+00	0.000000	0.00E+00	100.000	0.00E+00	0.00E+00	0.00E+00	2.21E+04	0.00E+00	1.50	27	0.00E+00	0.00E+00	0.00E+00
Rocket Motor, 2.75"	HA07	833	0.00E+00	3.450000	0.00E+00	0.028000	0.00E+00	96.522	0.00E+00	0.00E+00	0.00E+00	2.21E+04	0.00E+00	1.50	27	0.00E+00	0.00E+00	0.00E+00
Rocket, 2.25", SCAR	2.75" SCAR	833	0.00E+00	3.450000	0.00E+00	0.028000	0.00E+00	96.522	0.00E+00	0.00E+00	0.00E+00	2.21E+04	0.00E+00	1.50	27	0.00E+00	0.00E+00	0.00E+00
														Total Average Target Load Rate				3.70E-05

Note: Several columns have been hidden from the figures in this graphic due to space limitations.

Total Period C load rate for RDX at this discrete MC loading area

APPENDIX E

CONCEPTUAL SITE MODEL TABLES FOR GROUNDWATER AND SURFACE WATER

APPENDIX E.1

Groundwater CSM Tables

Site Name:	
Date:	

Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result		Units	Necessary Actions / Data Gaps	Data Interaction
METEOROLOGICAL DATA										
1	Precipitation	Yearly averages and seasonal variations	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Average: Maximum:				
2	Temperature	Yearly averages and seasonal variations	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Average: Maximum:				
PHYSICAL PROFILE										
3	Soil Type	Surface soil types, percentage paved area	☐ Literature ☐ Site Data ☐ Assumption					N/A		
4	Topography	Slope, Description of topography	☐ Literature ☐ Site Data ☐ Assumption					N/A		
5	Vegetation	Types and density of vegetation and estimated water usage	☐ Literature ☐ Site Data ☐ Assumption					N/A		
PRECIPITATION COMPONENTS → Sum of ET (6), Runoff (7) and Recharge (8) should equal Precipitation (1)										
6	Evapotranspiration	Portion of precipitation that evaporates or is used by vegetation	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Average: Maximum:				
7	Run-off	Portion of precipitation that travels overland to surface water body	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Average: Maximum:				Send to Surface Water Model
8	Recharge	Portion of precipitation that travels downward to the water table	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Average: Maximum:				Send to Vadose Zone Model

Site Name:	0
Date:	1/0/1900
Zone:	Vadose Zone

	Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result	Units	Necessary Actions / Data Gaps
Flow Parameters	1	Recharge	Portion of precipitation that travels downward to the water table				Minimum: 0 Average: 0 Maximum: 0	#VALUE!	
	2	Depth to Water Table	Average depth of water table below ground surface.	Literature Site Data Assumption			Minimum: Average: Maximum:		
	3	Material type	Type of soil	Literature Site Data Assumption			soil name	N/A	
	4	Saturated Horizontal Hydraulic	Average saturated horizontal hydraulic conductivity for soil name	Literature Site Data Assumption			Minimum: Average: Maximum:		
	5	Ratio of Vertical to Horizontal Hyd. Conductivity	Conductivity ratio for soil name	Literature Site Data Assumption			Minimum: Average: Maximum:		
	6	Specific Storage	Specific storage for soil name	Literature Site Data Assumption			Minimum: Average: Maximum:		
	7	Porosity	Porosity for soil name	Literature Site Data Assumption			Minimum: Average: Maximum:		
	8	Bulk Density	Bulk density of soil name	Literature Site Data Assumption			Minimum: Average: Maximum:		
	9	foc	Fraction of organic carbon for soil name	Literature Site Data Assumption			Minimum: Average: Maximum:		
	10	Longitudinal Dispersion	Dispersion in the direction of flow (downward)	Literature Site Data Assumption			Minimum: Average: Maximum:		
	11	Transverse Dispersion	Dispersion perpendicular to the direction of flow (horizontally)	Literature Site Data Assumption			Minimum: Average: Maximum:		
	9	Unsaturated Flow Equation	vanGenuchten -- rows 10-12 Brooks-Corey -- rows 13-15 Haverkamp -- rows 16-20 user-defined -- row 21	Literature Site Data Assumption				N/A	
	VanGenuchten Parameters								
	10	Residual Moisture Content	Minimum moisture content for soil name	Literature Site Data Assumption			Minimum: Average: Maximum:		
	11	Alpha	soil specific constant	Literature Site Data Assumption			Minimum: Average: Maximum:		
	12	Beta	soil specific constant	Literature Site Data Assumption			Minimum: Average: Maximum:		
	Brooks-Corey Parameters								
	13	Residual Moisture Content	Minimum moisture content for soil name	Literature Site Data Assumption			Minimum: Average: Maximum:		
	14	hb	soil specific constant	Literature Site Data Assumption			Minimum: Average: Maximum:		
	15	Lamda	soil specific constant	Literature Site Data Assumption			Minimum: Average: Maximum:		

	Haverkamp Parameters									
	16	Residual Moisture Content	Minimum moisture content for soil name	Literature Site Data Assumption			Minimum: Average: Maximum:			
	17	A'	soil specific constant	Literature Site Data Assumption			Minimum: Average: Maximum:			
	18	B'	soil specific constant	Literature Site Data Assumption			Minimum: Average: Maximum:			
	19	Alpha	soil specific constant	Literature Site Data Assumption			Minimum: Average: Maximum:			
	20	Beta	soil specific constant	Literature Site Data Assumption			Minimum: Average: Maximum:			
	User-defined Unsaturated Zone Properties									
	21	Table	Table of Pressure Head, Relative Conductivity and Moisture Content	Literature Site Data Assumption			Table		N/A	
Model Parameters	Model Information			Assumption						
	22	Model Width	Horizontal width of VS2DT model				Minimum: Average: Maximum:			
	23	Model Depth	Depth to bottom of model (should be greater than or equal to depth to water table)				Minimum: Average: Maximum:			
	24	Cell Size	Size of model cells				Minimum: Average: Maximum:			
	25	Total Time for Model	Length of time to run model				Minimum: Average: Maximum:			
	26	Timestep Size for Model	Output timestep size				Minimum: Average: Maximum:			

Site Name:	0
Date:	1/0/1900
Contaminant Name:	TNT

	Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result		Units	Necessary Actions / Data Gaps
Vadose Zone Model	1	Initial Concentration	Concentration in infiltrating water (from MC loading analysis)	☐ Assumption			Minimum: Average: Maximum:			
	Dispersion - Saturated Zone Model			☐ Assumption						
	2	Coefficient of molecular diffusion		☐ Assumption ☐ Assumption			Minimum: Average: Maximum:			
	3	Decay Constant	First order decay constant for TNT	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Average: Maximum:			
	4	Adsorption	None -- skip row 5 Linear Isotherm -- row 5	☐ Literature ☐ Site Data ☐ Assumption					N/A	
	Adsorption: Linear Isotherm			☐ Assumption						
	5	Kd	Equilibrium Distribution Coefficient - Kd = Koc*foc = * = 0				Minimum: Average: Maximum:	0 0 0		
Sat. Zone Model	6	Koc	Partition coefficient for TNT	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Average: Maximum:			
	Source Information - Saturated Model									
	7	Source thickness	Vertical length of TNT plume				Minimum: Average: Maximum:			
	8	Source width	Horizontal length of TNT plume perpendicular to flow				Minimum: Average: Maximum:			
	9	Initial Concentration	Initial concentration of TNT plume (from vadose zone model)				Minimum: Average: Maximum:			

Site Name:	0
Date:	1/0/1900
Contaminant Name:	HMX

	Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result		Units	Necessary Actions / Data Gaps
Vadose Zone Model	1	Initial Concentration	Concentration in infiltrating water (from MC loading analysis)	Assumption			Minimum:			
							Average:			
							Maximum:			
	Dispersion - Saturated Zone Model			Assumption						
	2	Coefficient of molecular diffusion		Assumption Site Data Assumption			Minimum:			
							Average:			
							Maximum:			
	3	Decay Constant	First order decay constant for HMX	Literature Site Data Assumption			Minimum:			
							Average:			
							Maximum:			
	4	Adsorption	None -- skip row 5 Linear Isotherm -- row 5	Literature Site Data Assumption					N/A	
	Adsorption: Linear Isotherm			Assumption						
	5	Kd	Equilibrium Distribution Coefficient - Kd = Koc*foc = * = 0				Minimum:	0		
							Average:	0		
							Maximum:	0		
Sat. Zone Model	6	Koc	Partition coefficient for HMX	Literature Site Data Assumption			Minimum:			
							Average:			
							Maximum:			
	Source Information - Saturated Model									
	7	Source thickness	Vertical length of HMX plume				Minimum:			
							Average:			
							Maximum:			
	8	Source width	Horizontal length of HMX plume perpendicular to flow				Minimum:			
							Average:			
							Maximum:			
	9	Initial Concentration	Initial concentration of HMX plume (from vadose zone model)				Minimum:			
							Average:			
							Maximum:			

Site Name:	0
Date:	1/0/1900
Contaminant Name:	RDX

	Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result		Units	Necessary Actions / Data Gaps
Vadose Zone Model	1	Initial Concentration	Concentration in infiltrating water (from MC loading analysis)	Assumption			Minimum:			
							Average:			
							Maximum:			
	Dispersion - Saturated Zone Model			Assumption						
	2	Coefficient of molecular diffusion		Assumption Site Data Assumption			Minimum:			
							Average:			
							Maximum:			
	3	Decay Constant	First order decay constant for RDX	Literature Site Data Assumption			Minimum:			
							Average:			
							Maximum:			
	4	Adsorption	None -- skip row 5 Linear Isotherm -- row 5	Literature Site Data Assumption					N/A	
	Adsorption: Linear Isotherm			Assumption						
	5	Kd	Equilibrium Distribution Coefficient - Kd = Koc*foc = * = 0				Minimum:	0		
							Average:	0		
							Maximum:	0		
Sat. Zone Model	6	Koc	Partition coefficient for RDX	Literature Site Data Assumption			Minimum:			
							Average:			
							Maximum:			
	Source Information - Saturated Model									
	7	Source thickness	Vertical length of RDX plume				Minimum:			
							Average:			
							Maximum:			
	8	Source width	Horizontal length of RDX plume perpendicular to flow				Minimum:			
							Average:			
							Maximum:			
	9	Initial Concentration	Initial concentration of RDX plume (from vadose zone model)				Minimum:			
							Average:			
							Maximum:			

Site Name:	0
Date:	1/0/1900
Contaminant Name:	Perchlorate

	Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result		Units	Necessary Actions / Data Gaps
Vadose Zone Model	1	Initial Concentration	Concentration in infiltrating water (from MC loading analysis)	Assumption			Minimum:			
							Average:			
							Maximum:			
	Dispersion - Saturated Zone Model			Assumption						
	2	Coefficient of molecular diffusion		Assumption Site Data Assumption			Minimum:			
							Average:			
							Maximum:			
	3	Decay Constant	First order decay constant for Perchlorate	Literature Site Data Assumption			Minimum:			
							Average:			
							Maximum:			
	4	Adsorption	None -- skip row 5 Linear Isotherm -- row 5	Literature Site Data Assumption					N/A	
	Adsorption: Linear Isotherm			Assumption						
	5	Kd	Equilibrium Distribution Coefficient - Kd = Koc*foc = * = 0				Minimum:	0		
							Average:	0		
							Maximum:	0		
Sat. Zone Model	6	Koc	Partition coefficient for Perchlorate	Literature Site Data Assumption			Minimum:			
							Average:			
							Maximum:			
	Source Information - Saturated Model									
	7	Source thickness	Vertical length of Perchlorate plume				Minimum:			
							Average:			
							Maximum:			
	8	Source width	Horizontal length of Perchlorate plume perpendicular to flow				Minimum:			
							Average:			
							Maximum:			
	9	Initial Concentration	Initial concentration of Perchlorate plume (from vadose zone model)				Minimum:			
							Average:			
							Maximum:			

Site Name:	0
Date:	1/0/1900
Zone:	Saturated Zone

Flow, Fate & Transport, Model Parameters

Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result		Units	Necessary Actions / Data Gaps
1	Soil Type		Literature Site Data Assumption			soil name			
Advection									
2	Groundwater velocity		Literature Site Data Assumption			Minimum: Average: Maximum:			
OR									
3	Horizontal Hydraulic Conductivity	Conductivity for soil name	Literature Site Data Assumption			Minimum: Average: Maximum:			
4	Hydraulic Gradient	Slope of the Water Table	Literature Site Data Assumption			Minimum: Average: Maximum:			
5	Porosity	Porosity of soil name	Literature Site Data Assumption			Minimum: Average: Maximum:			
Dispersion									
6	Longitudinal Dispersion	Dispersion in the direction of flow (horizontally)	Literature Site Data Assumption			Minimum: Average: Maximum:			
7	Ratio of Transverse to Longitudinal Dispersion	Dispersion ratio perpendicular to the direction of flow (horizontally)	Literature Site Data Assumption			Minimum: Average: Maximum:			
8	Ratio of Vertical to Longitudinal Dispersion	Dispersion ratio perpendicular to the direction of flow (vertically)	Literature Site Data Assumption			Minimum: Average: Maximum:			
Retardation									
9	Bulk Density	Density of soil name	Literature Site Data Assumption			Minimum: Average: Maximum:			
10	foc	Fraction of organic carbon (soil name)	Literature Site Data Assumption			Minimum: Average: Maximum:			
Model Parameters			Assumption						
11	Width of model	Larger than width of plume							
12	Length of model	Larger than final length of plume							
13	Time period for model								

APPENDIX E.2

Surface Water CSM Tables

Installation name	
Date:	
MC Loading area	

Row	**Data Type**	**Description**	**Source Type**	**Rationale**	**Reference(s)**	**Value/Result**	**Units**	**Necessary Actions / Data Gaps**
1	Contaminated area	MC loading area (from loading analysis)				Minimum: Most likely Maximum:		
Soil Information								
2	Predominant soil type	Surface soil types at MC loading area	☐ Literature ☐ Site Data ☐ Assumption				N/A	
3	Hydrologic soil group	Hydrologic soil group at MC loading area	☐ Literature ☐ Site Data ☐ Assumption				N/A	
4	Thickness of ground surface soil	Thicness of surface soil at MC loading area	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Most likely: Maximum:		
5	Soil organic content	Organic content in surface soil at MC loading area	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Most likely: Maximum:		
6	Soil bulk density	Soil bulk density of surface soil at MC loading area	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Most likely: Maximum:		
7	Soil particle density	Soil particle density of surface soil at MC loading area	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Most likely: Maximum:		
8	Air content in ground surface soil	Air content in surface soil at MC loading area	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Most likely: Maximum:		
9	Water content in surface soil	Water content in surface soil at MC loading area	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Most likely: Maximum:		
Metrological Information								
10	Precipitation	Annual precipitation	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Most likely: Maximum:		
11	Temperature	Ambient environmental temperature	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Most likely: Maximum:		
9	Wind speed	Yearly average wind speed	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Most likely: Maximum:		
General Information								
10	Land Use	Land use at MC loading area	☐ Literature ☐ Site Data ☐ Assumption				N/A	
11	Slope	Slope estimated from topographic data	☐ Literature ☐ Site Data ☐ Assumption			Minimum: Most likely: Maximum:		

Erosion of surface soil (using the Universal Soil Loss Equation, USLE)									
12	R	Rainfall and Runoff factor	Literature Site Data Assumption			Minimum: Most likely: Maximum:			
13	K	Soil erodibility factor	Literature Site Data Assumption			Minimum: Most likely: Maximum:			
14	LS	Topographic factor (influenced of length and steepness of slope)	Literature Site Data Assumption			Minimum: Most likely: Maximum:			
15	C	Cover and management factor	Literature Site Data Assumption			Minimum: Most likely: Maximum:			
16	P	Erosion control practice factor	Literature Site Data Assumption			Minimum: Most likely: Maximum:			
17	A	predicted soil loss	Literature Site Data Assumption			Minimum: Most likely: Maximum:			
Additional Model parameters									
18	Runoff coefficient	Portion of precipitation that travels overland to surface water body	Literature Site Data Assumption			Minimum: Most likely: Maximum:			
19	Groundwater recharge	Portion of precipitation that travels downward to the water table	Literature Site Data Assumption			Minimum: Most likely: Maximum:			
20	Thickness of root-zone soil	Approximate thickness of plant root-zone in soil	Literature Site Data Assumption			Minimum: Most likely: Maximum:			
21	Air content of root-zone soil	Air content of root zone soil	Literature Site Data Assumption			Minimum: Most likely: Maximum:			
22	Water content of root-zone soil	Water content of root-zone soil	Literature Site Data Assumption			Minimum: Most likely: Maximum:			

Installation name:	
Date:	
Munitions Constituent:	TNT

Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result	Units	Necessary Actions / Data Gaps
1	Source-term to ground surface soil	Yearly load to soil (from MC loading analysis)	Assumption			Minimum: Average: Maximum:		
2	Molecular weight	Molecular weight of TNT	Assumption Assumption					
3	Solubility	Water solubility of TNT	Literature Site Data Assumption			Minimum: Average: Maximum:		
4	Vapor pressure	Vapor pressure of TNT	Literature Site Data Assumption			Minimum: Average: Maximum:		
5	Henry's law constant	Henry's law constant of TNT	Literature Site Data Assumption			Minimum: Average: Maximum:		
6	Koc	Partition coefficient for TNT	Literature Site Data Assumption			Minimum: Average: Maximum:		
7	K_D	Equilibrium distribution coefficient	Literature Site Data Assumption			Minimum: Average: Maximum:		
8	Diffusion coefficient in air	Diffusion coefficient of TNT in air	Literature Site Data Assumption			Minimum: Average: Maximum:		
9	Half-life in air	Reaction half-life of TNT in air	Literature Site Data Assumption			Minimum: Average: Maximum:		
10	Half-life in soil	Reaction half-life of TNT in soil	Literature Site Data Assumption			Minimum: Average: Maximum:		
11	Half-life in water	Reaction half-life of TNT in water	Literature Site Data Assumption			Minimum: Average: Maximum:		

Installation name:	
Date:	
Munitions Constituent:	HMX

Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result	Units	Necessary Actions / Data Gaps
1	Source-term to ground surface soil	Yearly load to soil (from MC loading analysis)	Assumption			Minimum: Average: Maximum:		
2	Molecular weight	Molecular weight of HMX	Assumption Site Data Assumption					
3	Solubility	Water solubility of HMX	Literature Site Data Assumption			Minimum: Average: Maximum:		
4	Vapor pressure	Vapor pressure of HMX	Literature Site Data Assumption			Minimum: Average: Maximum:		
5	Henry's law constant	Henry's law constant of HMX	Literature Site Data Assumption			Minimum: Average: Maximum:		
6	Koc	Partition coefficient for HMX	Literature Site Data Assumption			Minimum: Average: Maximum:		
7	K_D	Equilibrium distribution coefficient	Literature Site Data Assumption			Minimum: Average: Maximum:		
8	Diffusion coefficient in air	Diffusion coefficient of HMX in air	Literature Site Data Assumption			Minimum: Average: Maximum:		
9	Half-life in air	Reaction half-life of HMX in air	Literature Site Data Assumption			Minimum: Average: Maximum:		
10	Half-life in soil	Reaction half-life of HMX in soil	Literature Site Data Assumption			Minimum: Average: Maximum:		
11	Half-life in water	Reaction half-life of HMX in water	Literature Site Data Assumption			Minimum: Average: Maximum:		

Installation name:	
Date:	
Munitions Constituent:	RDX

Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result	Units	Necessary Actions / Data Gaps
1	Source-term to ground surface soil	Yearly load to soil (from MC loading analysis)	Assumption			Minimum: Average: Maximum:		
2	Molecular weight	Molecular weight of RDX	Assumption Site Data Assumption					
3	Solubility	Water solubility of RDX	Literature Site Data Assumption			Minimum: Average: Maximum:		
4	Vapor pressure	Vapor pressure of RDX	Literature Site Data Assumption			Minimum: Average: Maximum:		
5	Henry's law constant	Henry's law constant of RDX	Literature Site Data Assumption			Minimum: Average: Maximum:		
6	Koc	Partition coefficient for RDX	Literature Site Data Assumption			Minimum: Average: Maximum:		
7	K_D	Equilibrium distribution coefficient	Literature Site Data Assumption			Minimum: Average: Maximum:		
8	Diffusion coefficient in air	Diffusion coefficient of RDX in air	Literature Site Data Assumption			Minimum: Average: Maximum:		
9	Half-life in air	Reaction half-life of RDX in air	Literature Site Data Assumption			Minimum: Average: Maximum:		
10	Half-life in soil	Reaction half-life of RDX in soil	Literature Site Data Assumption			Minimum: Average: Maximum:		
11	Half-life in water	Reaction half-life of RDX in water	Literature Site Data Assumption			Minimum: Average: Maximum:		

Installation name:	
Date:	
Munitions Constituent:	Perchlorate

Row	Data Type	Description	Source Type	Rationale	Reference(s)	Value/Result	Units	Necessary Actions / Data Gaps
1	Source-term to ground surface soil	Yearly load to soil (from MC loading analysis)	Assumption			Minimum: Average: Maximum:		
2	Molecular weight	Molecular weight of perchlorate	Assumption Site Data Assumption					
3	Solubility	Water solubility of perchlorate	Literature Site Data Assumption			Minimum: Average: Maximum:		
4	Vapor pressure	Vapor pressure of perchlorate	Literature Site Data Assumption			Minimum: Average: Maximum:		
5	Henry's law constant	Henry's law constant of perchlorate	Literature Site Data Assumption			Minimum: Average: Maximum:		
6	Koc	Partition coefficient for Perchlorate	Literature Site Data Assumption			Minimum: Average: Maximum:		
7	K_D	Equilibrium distribution coefficient	Literature Site Data Assumption			Minimum: Average: Maximum:		
8	Diffusion coefficient in air	Diffusion coefficient of perchlorate in air	Literature Site Data Assumption			Minimum: Average: Maximum:		
9	Half-life in air	Reaction half-life of perchlorate in air	Literature Site Data Assumption			Minimum: Average: Maximum:		
10	Half-life in soil	Reaction half-life of perchlorate in soil	Literature Site Data Assumption			Minimum: Average: Maximum:		
11	Half-life in water	Reaction half-life of perchlorate in water	Literature Site Data Assumption			Minimum: Average: Maximum:		

APPENDIX F

FATE OF MUNITIONS CONSTITUENTS MEMOS

MALCOLM PIRNIE
INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

Fate of Munitions Constituents in the Environment

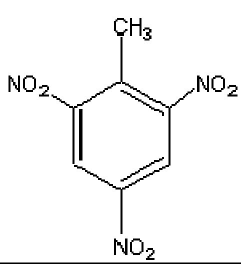
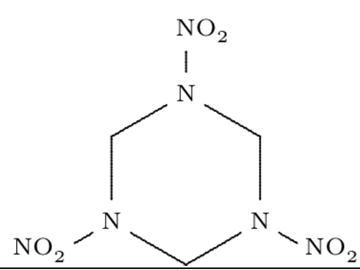
Jeffrey W. Talley, Ph.D., P.E.

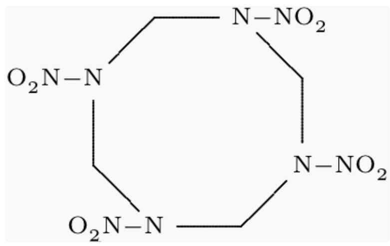
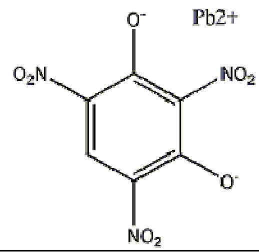
1 Introduction

Concerns have been raised over the potential environmental impacts of military ranges and training areas where detectable concentrations of explosives (ATSDR, 1995a; ATSDR, 1995b; ATSDR, 1997) and heavy metal contaminants (EPA, 2005) have been measured in soil, surface water and groundwater. The United States Marine Corps (Marine Corps) has initiated the Range Environmental Vulnerability Assessment (REVA) program to evaluate the potential for a release or threat of a release of munitions constituents (MC) from an operational range to an off-range area. This memorandum discusses the fate and transport in the environment of MC used on operational ranges.

The primary MC of concern include 2,4,6-trinitrotoluene (TNT); hexahydrol-1,3,5-trinitro-1,3,5-triazene (RDX); octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX); perchlorates; lead metal; and lead compounds such as the explosive lead azide (PbN_6) and lead styphnate ($PbC_6HN_3O_8 \cdot H_2O$) (EPA, 2005). The nitroaromatic and lead compounds are used as bursting explosives independently, as mixtures with each other, or in conjunction with other compounds in shells, bombs, grenades, excavation blasting, and some miscellaneous industrial processes (ATSDR, 1995a). Perchlorate is a component of rocket fuel and high explosive mixtures, and metallic lead is a component of small arms projectiles (ATSDR, 2005a; ITRC, 2005; ATSDR, 2005b). Other MC are used on operational ranges; however, the MC discussed here are among the most common and have been chosen as indicator MC for the REVA program (HQMC, 2006). Chemical structures for the above organic and organometallic MC are shown in Figure 1:

Figure 1: Structures for select organic and organometallic MC
(Wikipedia, 2006)

TNT:	RDX:
	

HMX:	$PbC_6HN_3O_8$:
	

Sources for MC include the stock compound manufacturing, munitions loading, assembly, and packing facilities and demilitarization of munitions stockpiles by explosion or incineration. On operational ranges, breached unexploded ordnance (UXO) and partially detonated (low-order detonation) ordnance can also be a source of MC to the environment. MC from these sources can enter the environment either through the atmosphere, through surface water, or via percolation into the soil (ATSDR, 1995a; Brannon and Pennington, 2002; Pennington et al., 2005). Because of the threat of severe health related affects from these compounds, understanding the fate and transport of these materials once released is crucial to ensuring protection of public health and the environment. Since military ranges and training areas are possible sources of contamination to adjoining non-Department of Defense (DoD) lands, there is urgency to study the MC and their fate and transport and to determine if contamination of adjoining lands and water supplies is possible or even in progress.

Focusing on a single MC molecule that is released and deposited on operational range topsoil, its fate may be among the following (or others not listed):

- Removal by vaporization or dust then deposited elsewhere or removed by degradation
- Infiltration into a shallow or deep aquifer then removed by degradation or transported elsewhere. In the groundwater, it may be captured by water supply wells then consumed by a well user, removed by degradation, or transported elsewhere, such as discharge to surface water.
- Transport by runoff into surface water, where ecological receptors may consume it or it may be removed by degradation
- Adsorption to the soil, where it may be removed by sequestration or degradation or leached to deeper soil or groundwater. In the soil, the contaminant may enter the food chain, where it eventually may be consumed.

The much larger quantities of MC potentially loaded to an operational range will take multiple paths and be divided among the atmosphere, surface water, and soil (McGrath, 1995).

Atmosphere: At operational ranges, MC can enter the atmosphere as vapors (from sublimation or compound volatilization) or particulates (i.e., fugitive dust generation). Low-order detonations and unfired but corroding items, as well as breached duds, may also contribute. At small arms ranges, lead dust may enter the air from the small arms barrel plume or fugitive dust generation. At rocket test sites, unburned perchlorate may enter the atmosphere in particulate form or be dissolved in any water byproduct of the firing process.

In general, the MC mentioned have low volatilization potentials, as shown by the vapor pressure data in Table 1. Also, the Henry's law constants are low. Only compounds with a Henry's law constant greater than 10^{-5} can volatilize significantly from water (Thomas, 1990; McGrath, 1995). It must be noted that, although MC may not be volatile, their transformation or degradation products may be volatile or semivolatile (McGrath, 1995).

Surface Water: MC can enter rivers, streams, and lakes directly when located adjacent to nearby ranges. This includes metallic lead from small arms ranges. Data in Table 1 show that MC compounds are sparingly soluble in water. Because they are soluble to some extent, all MC on ranges eventually will enter the topsoil or dissolve in the water where they come to rest. Because of the MC's low solubilities, however, transformation and degradation of the compounds will be competing with advective and dispersive transport of the dissolved material. When considering whether MC can be transported to adjacent non-DoD lands via surface or groundwater, consideration must be given to the quantity of MC actually loaded onto the range. (MC *loading* refers to a time integrated inventory of MC deposited on the range through normal range operations [often reported in kilograms per square meter].)

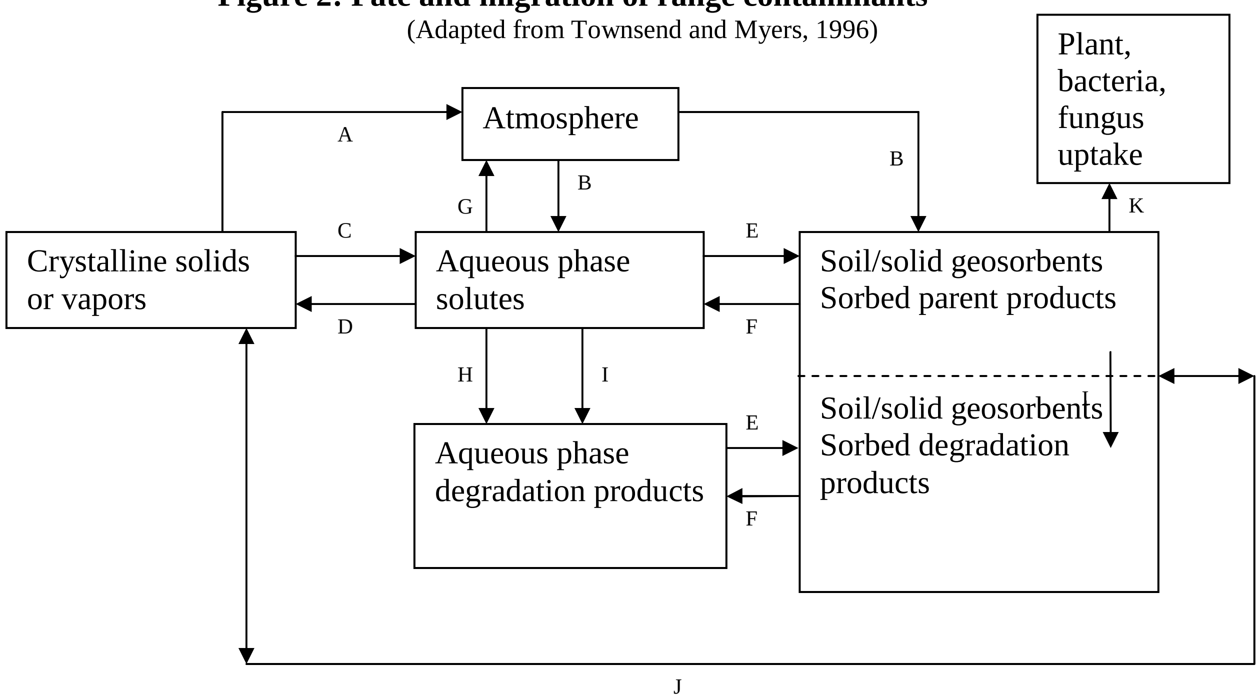
Soil: A direct release to soil occurs from spills, solid waste disposal, leaching from waste storage (including underground tanks at ranges), UXO, and direct projectile soil entry (EPA, 1989; U.S. Army, 1986). MC that bind to soil irreversibly will be retained and not leached into groundwater unless soil saturation has been reached. MC that can desorb will show retarded leaching into groundwater, which will be competing with degradation and transformation.

The percentage that each route will be used would be determined by the individual properties of the specific MC, the geological and physiographic properties of the range, and the amount of MC actually loaded onto the range during use (HQMC, 2006).

2 Environmental Fate and Migration

Migration of MC and their eventual fate in the environment depend on a multitude of factors, including advection; hydrodynamic dispersion; diffusion; photolysis; plant, bacterial, or fungal uptake; biotic and abiotic transformation; and sorption. MC loaded to training or testing ranges may migrate to other areas within the same range or to adjacent ranges. However, of greatest concern is that MC potentially may also be released to adjacent non-DoD land. Figure 2, adapted from Townsend and Myers (1996), outlines possible transport or degradation pathways for MC.

Figure 2: Fate and migration of range contaminants
(Adapted from Townsend and Myers, 1996)



The pathways indicated in the figure are as follows:

A) Fugitive dust generation (migration): Contaminants that have collected on surface soils may become fugitive dust.

B) Wet or dry deposition (migration): Particulate matter, fugitive dust, or solutions may be wet or dry deposited into surface water or surface soils.

C) Dissolution (migration and possible phase change): Particulate solids that have been deposited by munitions or migrated may dissolve into surface water after transport. Compounds that are not soluble will become suspended or dissolved solids.

D) Precipitation (migration and possible phase change): Changes in tide or other water flows may leave suspended contaminants on land. Soluble contaminants may precipitate as evaporation occurs from water bodies.

E) Adsorption (contaminant sequestration – formation of contaminant reservoirs): When water with dissolved contaminants or suspended solids moves over soil or suspended solids pass through contaminated water, the contaminants may become adsorbed onto soil (or underwater suspended solid). The affinity for the soil/solid to the contaminant will vary based on specific properties of both contaminant and the soil/solid. Any contaminants that are adsorbed are not free to move into deeper soil or groundwater until released. However, soils/solids that harbor contaminants pose risks from dermal contact and inhalation of dusts or ingestion of suspended solids.

F) Desorption (contaminant release): Water flowing over contaminated soil may be contaminated if the contaminant desorbs. The water path will then lead to contaminated groundwater or surface water.

G) Volatilization (migration): Contaminant solids with a high enough vapor pressure will be released as vapors. Solutions of contaminants with a high enough Henry's law constant may release vapors of the contaminating solute.

H) Photolysis (contaminant removal or new contaminant source): While in the atmosphere as vapors or fine particulates or in surface water with a sufficient amount of actinic flux, some contaminants are susceptible to photochemical degradation.

I) Biotic/abiotic transformation (contaminant removal or new contaminant source): Abiotic or biotic transformation of the contaminating molecules can occur, which removes the contamination from the environment; however, in some cases, the degradation products are just as toxic or even more toxic than the parent compound.

J) Vapor phase transport (migration): Contaminants with higher vapor pressures or higher Henry's law constants may feed a continuous evaporative flux, which can move by diffusion around soil pore sites.

K) Uptake by plants, fungus, or microorganisms (migration or reduction): For contaminants where this pathway is available with a high affinity, bioremediation is effective.

3 Chemical and Physical Properties of MC

The fate and transport of a chemical in the environment is, to a great extent, a function of the basic properties of the specific chemical. The MC's physical and chemical properties control the extent to which it will participate in the pathways described in Figure 2. Important chemical properties of MC are listed in Table 1.

Table 1: Chemical and Physical Properties of MC

	TNT	RDX	HMX	Ammonium Perchlorate	Elemental Lead
CAS ID	118-96-7	121-82-4	269-41-0	7790-98-9	7439-91-1
Molecular Mass	227.13 (g/mol)	222.26 (g/mol)	296.2 (g/mol)	117.5 (g/mol)	207.2 (g/mol)
Density	1.654	1.82 g/cc	1.90 g/cc (β form)	1.95 g/cc	11.34 g/cc
Melting Point (^oC)	80.1	204-206	276-287	No data	327.4
Boiling Point (^oC)	240 (explodes)	Decomp.	No data	345 (explodes)	1740
log K_{OW}	1.86-2.06	0.81-1.1	0.06-0.26	1.4E-6	No data
log K_{OC}	2.72	0.89-2.1	0.54-2.83	No data	No data
K_d	2 - 56	0.2-7.8	No data	Very low	High (Pb^{+2})
K_H (atm m^3/mol)	1.10E-08	1.2E-05	2.60E-15	Nonvolatile	Nonvolatile
Vapor Pressure (torr)	1.28E-6 (20^oC) 5.51E-6 (25^oC)	4.03E-9 (25^oC)	3.33E-14 (25^oC)	Nonvolatile	Nonvolatile
Water Diffusion (cm^2/s)	6.71E-06	7.15E-06	6.02E-06	No data	No data
Air Diffusion (cm^2/s)	0.064	0.074	0.063	No data	No data
Aerobic Biodegradability	Significant	Negligible	Negligible	No data	None for lead metal
Anaerobic Biodegradability	Moderate	Significant	Slow	No data	None for leadmetal
Toxicity	Possible carcinogen; toxic vapors	Possible carcinogen	No data	Thyroid toxic	Organ and neurotoxin
Photolysis	Rapid	Rapid	Rapid	No data	Yes for organolead
Hydrolysis	Alkaline sensitive	None	None	None	Yes for organolead
RMCL	44 µg/L	35 µg/L	No data	No data	No data
Water Solubility (mg/L)					
O^oC	100	No data	No data	No data	Insoluble
10^oC	110	28.9±1.0	1.21±0.04	No data	Insoluble
15^oC	200	No data	No data	No data	Insoluble
20^oC	130	42.3±0.6	2.6±0.01	No data	Insoluble
25^oC	150	59.9±1.2	5	200 g/L	Insoluble
26.5^oC	No data	59.9±1.4	No data	No data	Insoluble
30^oC	No data	75.7±1.1	5.7±0.1	No data	Insoluble
References	ATSDR, 1995a; McGrath, 1995	ATSDR, 1995b; McGrath, 1995	ATSDR, 1997; McGrath ,1995	ATSDR, 2005a; ITRC, 2005	ATSDR, 2005b

Notes:
g/mol – Grams per mole
g/cc – Grams per cubic centimeter
°C – Degrees Celcius
Kow – Octanol-water partition coefficient
Koc – Organic carbon-water partition coefficient
K_H – Henry's Law Constant
Atm m^3 / mol – Atmospheres * meters cubed per mole
cm^2/s – Centimeters squared per second
L/kg^2 – Liters / Kilogram
Mg/L – Milligrams per liter
µg/L – Micrograms per liter

To estimate the potential for MC to be released from an operational range, knowledge of the fate and transport specifics for the individual contaminant (some of which are listed above and below) is necessary, as well as an estimate of MC loading and the chemical, physical, and geologic setting of the environment into which it is released. When these parameters are reasonably well understood, MC fate and transport can be estimated or modeled. There are three caveats to estimating MC fate in the environment:

- Not all chemical, physical, and geologic parameters processes are well known or described for MC at specific ranges or under specific conditions; therefore, more data gathering may be necessary for accurate MC modeling.
- Care must be taken to select appropriate model methods.
- Reported degradation rates related to specific MC are varied and are likely affected by site-specific conditions, as shown in Table 2, which gives the readily available ranges of degradation rates for the indicator MC. Table 2 is based on a literature search of academic, industrial, and government publications and papers..

Table 2: Reported Degradation Rates

Explosive	Degradation Rate[a] (K-1, day-1)	Soil Type	Reference
HMX	0.15 due to photolysis	Unknown – lab study	EPA, 1988
	0.018 – 0.0092	Unknown – modeled figure	USACE, 2005
	0.0052 - 0.00030	Moist unsaturated soils (Fort Greeley, Yakima) 1.0 – 2.2 TOC	Jenkins, et al., 2003
	0	Surface soil, oxidizing conditions	Price, et.al., 1997
	0	Surface soil, mildly reducing conditions	Price, et.al., 1997
	0 – 1.44	Surface soil, highly reducing conditions	Price, et.al., 1997

Explosive	Degradation Rate[a] (K-1, day-1)	Soil Type	Reference
	0 – 0.0096	Aquifer soils	Pennington et al., 1995
	0.0375	Modeled – soil	EPA, 2006,
	0.0150	Modeled – sediment	EPA, 2006,
RDX	0.032 due to abiotic degradation	Unknown – lab study	Crocker et al., 2005
	0.0092 – 0.018	Unknown – modeled figure	USACE, 2005
	0.00737 – 0.00400	Moist unsaturated soils (from Fort Greeley range)	Jenkins et al., 2003
	0 – 0.168	Surface soil, oxidizing conditions	Price et al., 1997
	0 – 0.192	Surface soil, mildly reducing conditions	Price et al., 1997
	3.84 – 5.76	Surface soil, highly reducing conditions	Price et al., 1997
	0 – 0.0072	Aquifer soils	Pennington et al., 1995
	0.0375	Modeled – soil	EPA, 2006.,
	0.0150	Modeled – sediment	EPA, 2006.,
TNT	0.012 – 0.0058	Unknown – modeled figure	USACE, 2005
	0.01563	Anaerobic soil – graded silty sand	Brannon et al., 1999
	0.024	Aerobic soil – graded silty sand	Brannon et al., 1999
	0.0384	Anaerobic soil – silt	Brannon et al., 1999
	0.06	Aerobic soil – silt	Brannon et al., 1999
	0.06	Modeled – soil	EPA, 2006,
	0.024	Modeled – sediment	EPA, 2006,

[a] Unless noted, degradation is due to biotic and abiotic mechanisms

4 Bioavailability and Soil Properties

How we define "availability" is critical to our understanding of the fate and transport of MC and their impact to the environment. The ***available*** portion of a compound in soil is generally described as the portion of a compound that can be extracted from soil, typically by an organic solvent and without alteration to the chemical structure of the compound (Northcott and Jones, 2001). The ***bioavailable fraction*** is defined as the quantity of a chemical in soil or another environmental medium that is actually accessible to an organism. Bioavailability, the term as used here and as commonly used among soil and environmental scientists, does not relate to toxicity (Chung and Alexander, 1998).

Researchers have shown that for microorganisms, earthworms, and other organisms, the bioavailability of a compound decreases with increasing contaminant-soil contact time (Kelsey et al., 1996; White et al., 1997; Leppanen and Kikkonen, 1998). This decrease may result from chemical oxidation reactions incorporating contaminants into organic matter, diffusion into very small pores, and absorption into organic matter – all related to the chemical aging/weathering process.

It is generally agreed that a necessary aspect to bioavailability is the release of a solid-bound contaminant. Therefore, before a compound can be bioavailable, it must actually be physically available. This release or ***physical availability*** is defined as the capability of a chemical for transport from its bound state on or within a geosorbent to a new environmental medium. Physical availability is linked to the portion of a contaminant that partitions into the aqueous phase compared to how much is sequestered and the energy required to desorb the chemical from the matrix (Chung and Alexander, 1998). Thus, physical availability can be assessed using more traditional aqueous desorption methods and the novel thermal programmed desorption - mass spectrometry experiment.

Since the mechanisms controlling MC availability in soils are likely similar to the mechanisms fundamentally developed for non-polar organic compounds, a brief review of the important soil constituents that control the MC fate processes (i.e., sorption, desorption, and partitioning) is provided here.

4.1 Quartzite Sand and Clay Minerals

In typical soils, minerals make up over 90% of the soil matrix and, for the most part, are composed of various arrangements of silica, aluminum, oxygen, and iron (Sparks, 1995). These minerals can be viewed as persistent chemicals in the environment with the surface of most of their crystal structures having a surface charge. The mineral matrix/crystal itself is impenetrable and rigid; hence, sorption to mineral components is a surface or near surface interaction (Xing and Pignatello, 1998).

Quartz, the second most abundant mineral in the Earth's crust, is important to MC binding because it dominates in sands, many soils, and some sediment. Quartzose sand is essentially pure SiO_2, but it may contain trace amounts of other elements. A large number of nitroaromatic compounds (NACs), such as TNT, have minimal interaction with the surface of quartz grains. For example, Haderlein and Schwarzenbach (1993) showed that NACs are weakly adsorbed to silica. The MC sorption to clay minerals, on the other hand, is of greater significance.

Clay minerals are a group of sheet silicates with related atomic structures. Most are hydrated aluminum or magnesium silicates produced by weathering rocks. Clays are usually very fine grained, often less than 1 microns in size, which results in the presence of large surface areas available for the exchange of ions and molecules between the solids and surrounding solutions. Two of the most common clay minerals are kaolinite and montmorillonite.

Kaolinite is a common secondary mineral formed from the weathering of aluminous silicates and is a component of many soils. Kaolinite clays are two-layer structures with a chemical formula of $Al_4(Si_4O_{10})(OH)_8$. The atomic structure of kaolinite is based on alternating layers of SiO_4 tetrahedra and OH and Al^{3+}. The alternating layers present two distinctly different potential adsorption surfaces: 1) an alumina surface with surface hydroxyl groups and 2) a silica surface with oxygen-bridged silica atoms (siloxane) (van Duin and Larter, 2001). The surfaces that present siloxane to the environment are hydrophobic, so these surfaces are the preferred sites for the adsorption of non-polar organic molecules (Yariv and Cross, 2002). Given the presence of these relatively hydrophobic surfaces and kaolinite's high surface area, non-polar organic molecules, such as TNT, are bound more tightly to kaolinite as compared to quartz sand.

Montmorillonite, the other most common clay mineral, dominates modern clay-rich sediments. Montmorillonite is a crystal structure based on groups of three layers, where single sheets of $(Al, Mg)(O, OH)_6$ octahedra are sandwiched between two sheets of SiO_4 tetrahedra. Through expansion, the three-layer clay can take up extra water or other fluids. Because the crystal structure expands, montmorillonite is sometimes referred to as expandable or swelling clay. The extent of expansion in montmorillonite clays largely determines the available sorption sites. Therefore, an increase in swelling results in an increase in sorption of MC.

4.2 Natural Organic Matter

Natural organic matter (NOM) is an assemblage of organic compounds derived from plants and animals and found in practically every terrestrial environment. NOM may include recognizable biopolymers like proteins, lignin, and cellulose, but also a menagerie of macromolecules from the partial degradation and cross-linking of organic residues remaining from organisms or photochemical reactions (Haderline and Schwarzenbach, 1993). NOM is predominantly made of carbon, but can also consist of almost as many oxygen atoms as carbon in its atomic structure. Naturally, the atomic structure of the material depends on the ingredients supplied to a particular water or soil.

Soil organic matter (SOM), a subset of NOM, is decomposed plant and microbial material, with the bulk of SOM consisting of humic substances. Substances are referred to as humic substances if they are soluble in aqueous base and humin or kerogen if they are not. The humic substances are further subdivided into fulvic acids if they are soluble at all pHs and humic acids if they are not soluble in acidic conditions (less than or equal to pH 2) but are soluble at higher pHs. Humic substances are refractory mixtures or macromolecules with molecular weights ranging from a few hundred to many tens of thousands of grams per mole. Partitioning into humic substances may be important in the sorption of nonionic organic chemicals, like TNT, and could be a mechanism of their aging in soils and sediments.

5 Discussion of Fate and Transport of Individual MC

For lands used as military munitions ranges, little concern stems from MC landing on soil and slowly dissipating (other than possible occupational exposure to a user of the range for training or testing). This assumes the MC remain only on the range and do not migrate off range at an unacceptable level.

For any prediction of MC fate, not only is MC loading an important parameter, but parameters such as soil characteristics at the ranges, depth to groundwater, and proximity to surface water are necessary as well. Even the type of range should be considered. Pennington et al. (2002) have shown that various types of military testing and training ranges differ in the contaminants present. For example, surface soils near targets on antitank rocket ranges may have extremely high concentrations of HMX (parts per million level), while soils near artillery range targets may have only low concentrations of TNT and RDX present (parts per billion [ppb] level).

As shown on the physical and chemical property tables in Section 3.0, each of the MC considered reacts differently in the environment. The following section discusses the fate of individual MC in the environment.

5.1 ***TNT***

Adsorption and transformation are the primary processes influencing the fate and transport of TNT. Volatilization is not an important mechanism for solid TNT due to a high solubility, low Henry's law constant, and low vapor pressure (McGrath, 1995).

TNT does bind to soil, but the measured and estimated soil organic carbon adsorption coefficients of 300-1100 indicate that TNT does not strongly partition from surface waters to soil and sediments (Spanggord et al., 1985). Two types of tests have been conducted to assess TNT's partitioning affinity to soil and sediment:

- Short-term laboratory studies: For example, Spanggord et al. (1985) exposed uncontaminated surface soils from ammunition plants to TNT. Limited adsorption was found with an average soil-water partition coefficient (Kd) of 4. Then almost all of the TNT adsorbed was desorbed after a 24-hour period (although multiple extractions were required).

- Long-term laboratory studies: For example, Kayser and Burlinson (1988), showed that in long-term lysimeter studies (six months) where TNT was added to the top of soil columns, the TNT was retained by the soil column with samples taken every two weeks. Biodegradation products were not seen, but two transformation products were identified.

The effectiveness of soil at sequestering TNT may depend partially on the distance required to be traveled from the TNT exposure point in the topsoil to groundwater. Adherence to soil, as well as the transformation seen of TNT in soil to other hazardous compounds, creates an environmental reservoir for TNT that is an obstacle to remediation (Young, 2006). It has been shown that sequestration of TNT is highest in soils with high organic carbon content (Pennington et al., 1995). In soil, solid chunks of TNT, either buried or exposed on the soil surface, can remain unchanged for years (Rosenblatt, 1980). Smaller amounts may undergo photolysis in surface soils (Ryon et al., 1984).

TNT can undergo transformation via photochemical and microbiological processes in soil (Walsh et al., 1995). The three nitro groups reduce the electron density of the aromatic ring, impeding electrophilic attack (Rieger and Knackmuss, 1995). The electron deficiency of the ring system favors initial reductive reactions by microorganisms in aerobic and anaerobic conditions. Figure 3 illustrates the transformation pathways for TNT.

Figure 3: TNT transformation pathways
(Nishino and Spain, 2002)

In water, TNT does not undergo hydrolysis, as shown by the stability of the compound in seawater (Hoffsommer and Rosen, 1973). However, there is a fast photolysis with half-lives estimated at 0.16-1.28 hours based on TNT residing in sunlit natural water (Howard et al., 1991). TNT also undergoes microbial degradation in surface water, but at a slower rate. In air, TNT may be expected to undergo similar photolysis with an estimated half-life of 3.7-11.3 hours (Howard et al., 1991).

The fate of TNT released to water is likely to be photolysis in surface water where there is sufficient light. TNT that is not degraded and enters sediments and TNT directly released to soil is sequestered with respect to deeper soil or groundwater. However, there is a breakthrough possibility, and when the receptor sites in the soil are all occupied with TNT, additional TNT will pass freely to deeper soil and groundwater, where it may be subject to biotic/abiotic transformation processes and transport as a dissolved constituent of groundwater (Townsend and Myers, 1996).

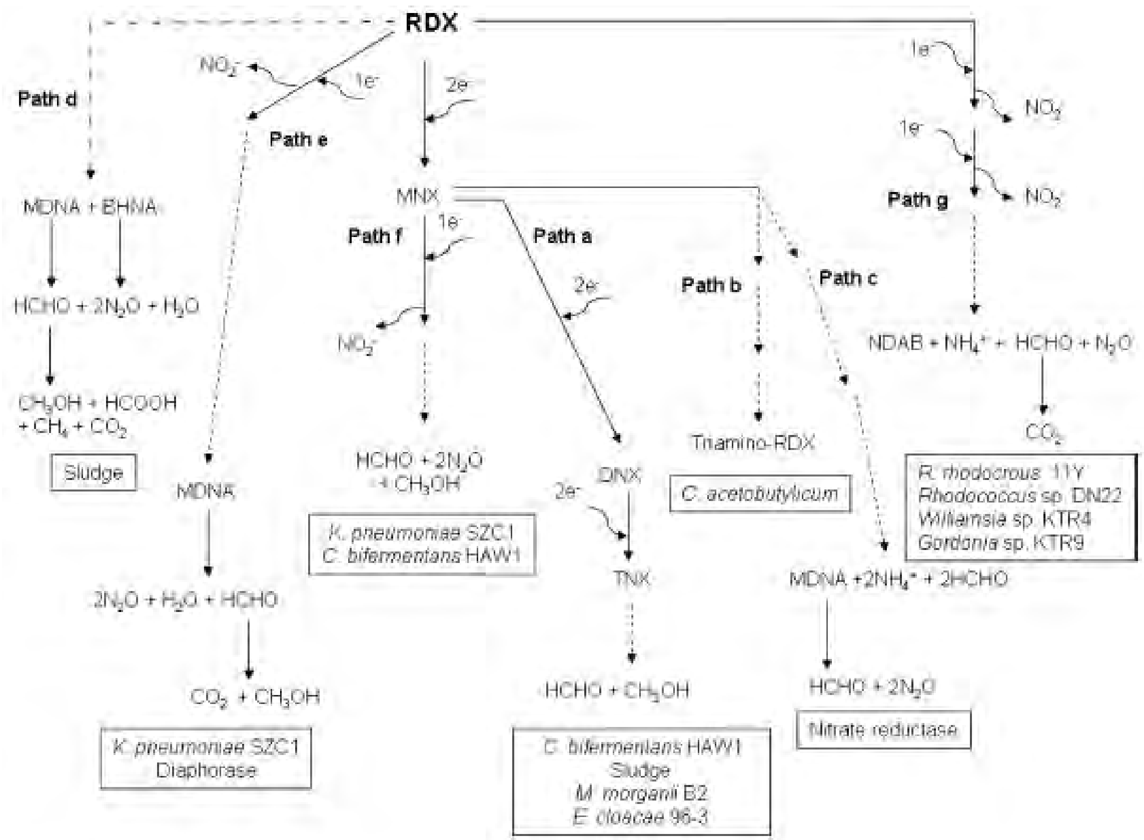
5.2 RDX

RDX has a lower vapor pressure than TNT; however, it can exist in both vapor and particulate phase in the atmosphere (Eisenreich, Looney, and Thornton, 1981). The solubility of RDX is also lower than that of TNT; yet it has a higher Henry's law constant. This combination of properties indicates that RDX may partition equally between the atmosphere and surface water; however, volatilization of soluble RDX is a slow transport process (Eisenreich, Looney, and Thornton, 1981; Lyman et al., 1982).

K_{OC} values range from 63.1 to 270 (ATSDR, 1995b), indicating medium-to-high mobility in soil. RDX soil-to-groundwater leaching can be expected. Experimental data show RDX is not readily bound to soil, and adsorption to sediment and particulate matter should not be significant (ATSDR, 1995b). Although there is no significant adsorption to sediment, adsorption increases with greater clay or organic matter content. In general, soils adsorb TNT to a greater extent than they adsorb RDX (Haderlein et al., 1996). As a result, RDX may be expected to show higher relative mobility than TNT, as observed by Brannon and Myers (1997). Soils in this mobility study were sterilized by gamma irradiation; however, unaccounted abiotic transformations (especially in TNT) may have influenced the observation.

In anaerobic environments, the biotic transformation of RDX is possible. Typically, this is through denitration and reduction and occurs at a much lower rate than TNT (Brannon and Pennington, 2002). Although all transformation products are not always observed, Crocker and Indest (2006) postulated the following degradation pathway:

Figure 4: Biodegradation pathway of RDX
(Crocker and Indest, 2006)



Notes:
MDNA: Methylenedintramine
NDAB: 4-nitro-2,4-diazabutanal
DNX: hexahydro-1,3-dinitroso-5-nitro-1,3,5-triazine
TNX: hexahydro-1,3,5-trinitroso-1,3,5-. triazine
BHNA: bis-(hydroxymethyl)nitramine

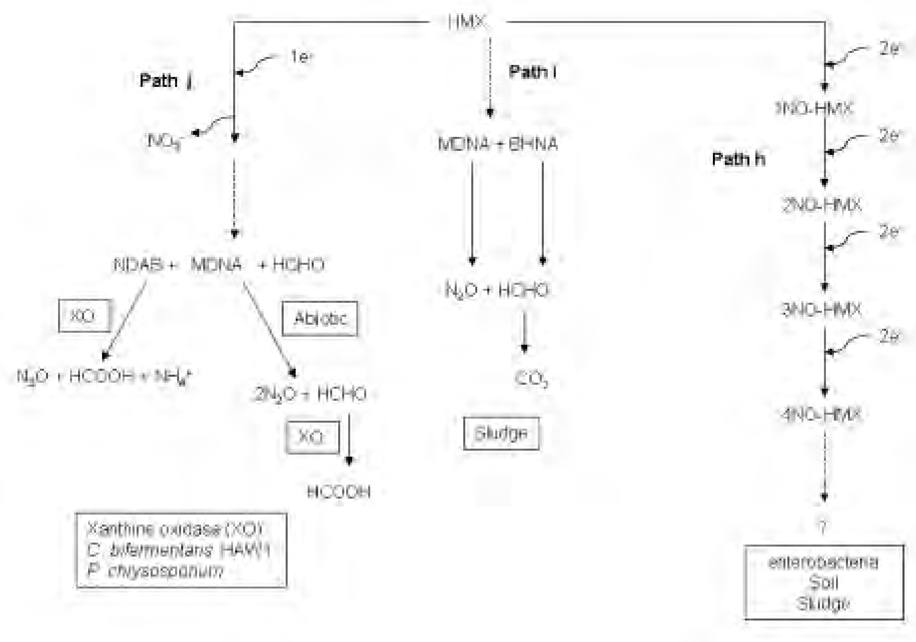
5.3 *HMX*

There are little data on the adsorption of HMX on soil and sediment. The Kd values in Table 1 indicate, like RDX, less adsorption and higher mobility might occur than with TNT.

HMX has an extremely low vapor pressure and small Henry's law constant, indicating it does not readily volatilize from soil or water. Its small water solubility indicates HMX has limited mobility.

HMX is shown to be more biologically recalcitrant than both TNT and RDX. However, in anaerobic conditions, it can be degraded by anaerobic microorganisms (Crocker and Indest, 2006). A possible degradation pathway is shown in Figure 5:

Figure 5: Biodegradation pathway of HMX
(Crocker and Indest, 2006)



5.4 Perchlorate

Perchlorate is typically found as perchloric acid or ionic salts (e.g., ammonium, sodium, potassium as the cation and perchlorate as the anion). Perchlorate salts form with nearly every metal on the periodic table, most of them soluble (Cotton and Wilkinson, 1988). With regard to toxicity and environmental fate and transport, the cation is typically a spectator ion only and perchlorate itself is the subject of concern. There appears to be some natural production of perchlorate (ATSDR, 2005a), especially in arid regions, but contamination through anthropogenic sources can be much more concentrated and have much greater environmental impacts.

Perchlorate is extremely soluble, stable, and mobile. Therefore, very persistent contaminant plumes may exist when perchlorate salts are introduced into surface and groundwater. Very little is known about the interaction of soil/sediment and perchlorate; however, like nitrate, perchlorate may not substantially adsorb onto soils or sediment. This can be surmised from the fact that perchlorate is not likely to serve as a ligand (Cotton and Wilkinson, 1988). As an ionic salt, perchlorate is not prone to vaporization. The only reduction paths for perchlorate may be naturally occurring perchlorate reducing bacteria, remediation activities such as ion exchange treatment, or soil oxidation-reduction potential manipulation. Some plants have been found to uptake perchlorate with their root systems and concentrate it in their tissues.

Since perchlorate does not appreciably bind to soil particles and because it is extremely soluble, it will have a very high mobility through soil. The speed of this mobility is likely to be proportional to concentration, volume of water present, and advection rate. It is believed that sufficient water infiltration will leach all perchlorate from soil (ATSDR, 2005a).

The fate of perchlorate may be continuous build-up in natural waters, proportional to the amount deposited, with only a small removal term.

A small amount of perchlorate may remain in the vadose zone in arid regions as an evaporite. Some small amounts may also be held in solution in the irreducible water content of the soil.

5.5 Lead Metal and Salts

Lead enters water from sources such as atmospheric fallout, runoff, wastewater, range activities; little is transferred from natural ores. Metallic lead is attacked by pure water in the presence of oxygen, but if the water contains carbonates and silicates, protective films are formed preventing further attacks. That which dissolves tends to forms ligands. Lead is effectively removed from the water column to sediment by adsorption to organic matter and clay minerals, precipitation as insoluble salt, and reaction with hydrous iron and manganese oxide. Under most circumstances, adsorption predominates.

Lead released to the atmosphere exists primarily as particulates and eventually is removed by wet or dry deposition (ATSDR, 2005b). Lead has been reported in sediment cores of lakes in northern Ontario and Quebec, Canada, a far distance from lead release sites. This indicates long-range transport of lead via the atmosphere may be important (Evans and Rigler, 1985). In contrast, Berndtsson (1993) has reported that local sources of lead (less than 10 kilometers from deposition site) dominate contamination sites. In either case, the transport of lead through the air with final deposition to surface water or soil is an important transport mechanism. For these reasons, lead's ability to contaminate adjacent lands should be proportional to the amount of lead loading at ranges.

The most stable form of lead in natural water is a function of the ions present, the pH, and the reduction-oxidation potential. In oxidizing systems, the least soluble common forms are probably the carbonate, hydroxide, and the hydroxycarbonate. In reduced systems where sulfur is present, PbS is the stable solid. The solubility of lead is 10 ppb above pH 8; below pH 6.5, solubility can approach or exceed 100 ppb. Pb^0 and Pb^{+2} can be oxidatively methylated by naturally occurring compounds such as methyl iodide and glycine betaine. This can result in the dissolution of lead already bound to sediment or particulate matter. Particles small enough may also be pushed through soil by water infiltration; however, larger particles will remain physically filtered by the soil.

Some solid lead in water will eventually be converted to the Pb^{+2} cation, with the rate increasing in more acidic water. However, the mechanism is poorly understood; therefore, the transport of solid lead (by transformation to Pb(II)) cannot be reliably predicted. The solubility of the Pb^{+2} cation depends on potential anions present, as well as water pH. In alkaline water, Pb^{+2} may precipitate as a carbonate or hydroxide compound. In acidic water, these compounds cannot be found, but any sulfate ion present may precipitate lead under acid conditions and will precipitate lead at a pH less than 4. In natural waters, the lead cation is more likely to be carried as colloidal or larger particles of lead carbonate, hydroxide, oxide, sulfide, sulfate, or other slightly soluble lead compounds.

Lead will be retained in the upper 2-5 centimeters of soil with at least 5% organic matter or at pH 5 or above. Leaching is not important under normal conditions. It is expected to slowly undergo speciation to the more insoluble sulfate, sulfide, oxide, and phosphate salts.

Unlike perchlorate, the migration of lead in soil is affected by a very large affinity for adsorption at mineral surfaces, formation of organic-lead complexes and chelates with soil organic matter, and electrostatic interaction with soil (ATSDR, 2005b). These interactions are strong enough that the accumulation of lead in soil is a function of the rate of deposition, with very little transported back to surface water or into groundwater except under acidic conditions.

At sites with acidic soil, such as near lead smelting plants, or in areas prone to acid rain, conditions may be favorable for an increased rate of lead running off to surface water or leaching to groundwater.

Both plants and animals can bioaccumulate lead. Lead does not appear to bioconcentrate significantly in fish but does in some shellfish, such as clams and mussels. Evidence suggests that lead uptake in fish is localized in the mucous on the epidermis, the dermis, and scales so that the availability in edible portions does not pose a human health danger. Since lead is an element, there is no transformation possible that will remove or degrade it. Instead of a removal or degradation term, there is only an allowance for moving lead from one storage location to another.

Sediment microorganisms are able to directly methylate certain inorganic lead compounds. Under appropriate conditions, dissolution due to anaerobic microbial action may be significant in subsurface environments. For example, the mean percentage removal of lead during some activated sludge process has been observed at 82% and was almost entirely due to the removal of the insoluble fraction by adsorption onto the sludge floc and, to a much lesser extent, precipitation.

6 CONCLUSION

Table 3 lists the modes shown in Figure 2 and an *estimate* of each mode's importance to an MC based on the generalizations discussed above (site geochemistry also has an important influence).

Table 3: Importance of Modes of Migration, Removal, or Transformation on Munitions Range Contaminants

Mode (See Figure 2)	TNT	RDX	HMX	Perchlorate	Pb(II)
A - Dust	M	M	M	I	I
B - Deposition	M	M	M	I	I
C - Dissolution	M	U	M	I	M
D - Precipitation	M	U	U	I	I
E - Adsorption	I	M	M	U	I
F - Desorption	I	M	M	U	M
G - Volatilization	U	L	L	U	U
H - Photolysis	I	N	N	U	U
I - Transformation	I	L	N	M	U
J - Plant/animal uptake	I	N	N	M	M

Note: I - Important to fate or transport
M - Moderately important to fate or transport
L - Limited importance to fate or transport
U - Unimportant to fate or transport

In conclusion, a summary of the fates of the individual contaminants, as we can determine them with as of yet limited understanding, follows:

- TNT is adsorbed onto soil from surface water or direct deposition. It slowly returns to surface water, slowly enters groundwater, or is degraded while on the soil. In shallow surface water, it may be degraded by photolysis. Degradation products are also MC, which may be exposed to the same transport and fate mechanisms as the parent, TNT. TNT's fate on the ground surface or in the vadose zone is to slowly leach into groundwater unless degraded first. The vadose zone potentially maintains a long-term (or permanent for some soil types) storage reservoir for TNT; however, further study of this compound and its soil interaction is required.

- RDX and HMX are adsorbed less on soil than TNT and, because of lower solubility, have a limited but persistent and quicker migration from surface to subsurface and groundwater. These compounds also have degradation compounds, which are not as well studied. The vadose zone potentially maintains a long-term storage reservoir for RDX/HMX, depending on the clay or organic material content; however, further study of these compounds and their soil interaction is required.
- Perchlorate is very soluble, and there is little to no soil adsorption. Surface and groundwater contamination concentrations continue to build as a function of perchlorate loading unless checked by known perchlorate reducing bacteria. The vadose zone is not expected to be a significant sink for perchlorate. Perchlorate has only a limited presence while migrating through.
- Lead has low mobility and extremely high soil affinity. Its long-range air transport increases its presence even in areas where direct deposition has not occurred. The extremely high soil interaction affinity indicates that the vadose zone is a permanent repository for lead. Slow migration to groundwater may occur with increased speed as soil within the water plume becomes saturated. However, soil acts as a filter for particulate lead. Actual munitions range modeling may be enigmatic because of a lack of data on how metallic lead is oxidized in these areas.

References

U.S. Army Medical Research and Development Command (U.S. Army). 1986. Demilitarization of conventional ordnance: Priorities for database assessments of environmental contaminants. Document no. AD UCRL-15902.

Agency for Toxic Substances and Disease Registry (ATSDR). 1995a. Toxicological profile for 2,4,6-trinitrotoluene." Public Health Service, U.S. Department of Health and Human Services.

------ 1995b. Toxicological profile for RDX. Public Health Service, U.S. Department of Health and Human Services.

------ 1997. Toxicological profile for HMX. Public Health Service, U.S. Department of Health and Human Services. Prepared by Sciences International, Inc.

------ 2005a. Draft toxicological profile for lead. Public Health Service, U.S. Department of Health and Human Services.

------ 2005b. Toxocological Profile for Perchlorates (Draft for public comment). Public Health Service, U.S. Department of Health and Human Services.

Berndtsson, R. 1993. Small-scale spatial patterns of bulk atmospheric deposition. *J. Environ Qual* 22:349-360.

Brannon, J.M., P. Deliman, C. Ruiz, C. Price, Q. Mohammed. 1999. Conceptual model and process descriptor descriptions for fate and transfer of UXO. Technical Report IRRP-99-1.

Brannon, J.M. and J.C. Pennington. 2002. Environmental fate and transport process descriptors for explosives. U.S. Army Corps of Engineers Engineer Research and Development Center, ERDC/EL TR-02-10.

Brannon, J.M. and T.E. Myers. 1997. Review of fate and transport processes of explosives. U. S. Army Corps of Engineers Waterway Experiment Station, Technical Report IRRP-97-2.

Chung, N. and M.Alexander. 1998. Differences in sequestration and bioavailability of organic compounds aged in dissimilar soils. *Environ. Sci. Technol.* 32 (7): 855 - 860.

Cotton, F. A. and G.Wilkinson. 1988. *Advanced inorganic chemistry*, 5th ed. p 745. New York: Wiley.

Crocker, F.H. and K. Indest. 2006. Biodegradation of the cyclic nitramine explosives RDX, HMX, and CL-20. *Appl. Microbiol. Biotechnol.* 73:274-290.

Crocker, F.H., K.T. Thompson, J.E. Szecsody, H.L. Fredrickson. 2005. Biotic and Abiotic Degradation of CL-20 and RDX in Soils. *J. Environ. Qual.* 34:2208-2216.

Eisenreich, S. J., S. B. Looney, J. D. Thornton. 1981. Airborne organic contaminants in the Great Lakes ecosystem. *Environ Sci Technol* 15:30-38.

Environmental Protection Agency (EPA). 1989. Treatability potential for EPA listed hazardous wastes in soil. EPA/600/S2-89-011. Doc no. PB89-166591.

------. 2005. *Handbook on the management of munitions response actions* (Interin Final). EPA 505-B-01-001.

------. 2006. *EPI Suite Software. Updated 2006.*

Evans, R. D. and F. H. Rigler 1985. Long distance transport of anthropogenic lead as measured by lake sediments. *Water Air Soil Pollut* 24:141-151.

Haderlein, S.B. and R.P. Schwarzenbach. 1993. Adsorption of substituted nitrobenzenes and nitrophenols to mineral surfaces. *Env. Sci. Technol*. 27:316-326.

Haderlein S.B., K.W. Weissmar, R.P. Schwarzenback. 1996. Specific adsorption of nitroaromatic explosives and pesticides to clay minerals. *Environmental Science and Technology* 30:612-622.

Headquarters, U.S. Marine Corps (HQMC). 2006. Range environmental vulnerability assessment (REVA) user's guide for installation managers (Preliminary draft).

Hoffsommer, J. C. and J. M. Rosen. 1973. Hydrolysis of explosives in sea water. *Bull Environ Contam Toxicol* 10(2): 78-79.

Howard, P. H., R. S. Boethling, W. F. Jarvis, et al. 1991. *Handbook of environmental degradation rates,* 454-455. Chelsea, MI: Lewis Publishers.

Interstate Technology & Regulatory Council (ITRC). 2005. Perchlorate: Overview of Issues, Status, and Remedial Options. PERCHLORATE-1. http://www.itrcweb.org.

Jenkins, T.F., C. Bartolini, T.A. Ranney. 2003. Stability of CL-20, TNAZ, HMX, RDX, NG, and PETN in moist, unsaturated soil. ERDC/CRREL TR 03-7.

Kayser, E. G. and N. E. Burlinson. 1988. Migration of explosives in soil: Analysis of RDX, TNT, and tetryl from carbon-14 lysimeter study. *J Energetic Materials* 6(1-2): 45-71.

Kelsey, J.W. and M. Alexander. 1996. Declining bioavailability and inappropriate estimation of risk of persistant compounds. *Environmental Toxicology and Chemistry* 16:582-585.

Leppanen M.T. and JVK Kikkonen. 1998. Factors affecting feeding rate, reproduction and growth of an oligochaete Lumbriculus variegatus. *Hydrobiologia*. 377:183

Lyman W.J., W.F. Reehl, D.H. Rosenblatt. 1982. *Handbook of chemical property estimation methods: Environmental behavior of organic compounds*. New York, NY: McGraw-Hill Book Company.

McGrath, J.C. 1995. Review of formulations for processes affecting the subsurface transport of explosives. U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report IRRP-95-2 and references therein.

Nishino, S.F. and J.C. Spain. 2002. Biodegradation, transformation and bioremediation of nitroaromatic compounds. In C.H. Hurst, G.R. Knudsen, M.J. McIlnerney, L.D. Stetzenbach, and M.V. Walter (eds.) *Manual of Environmental Microbiology*, 2nd edition. ASM Press, Washington, DC.

Northcott, G. L. and K. C. Jones. 2001. Partitioning, extractability, and formation of nonextractable PAH residues in soil. 1. Compound differences in aging and sequestration. *Environ. Sci. Technol*. 35:1103–1110.

Pennington, J.C., C.A. Hayes, K.F. Meyers, M. Ochman. 1995. Fate of 2,4,6-trinitrotoluene in a simulated compost system. *Chemosphere* 30:429-438.

Pennington, J.C., T.F. Jenkins, G. Amplemn, S. Thibout. 2002. Distribution and fate of energetics on DoD test and training ranges: Interim report 2. U.S. Army Corps of Engineers, ERDC TR-02-8.

------. 2005. Distribution and fate on DoD test and training ranges: Interim report 5. U.S. Army Corps of Engineers, ERDC TR-05-2 and references therein.

Price, C.B., J.M. Brannon, C.A. Hayes. 1997. Effect of redox potential and pH on TNT transformation in soil-water slurries. *Journal of Environmental Engineering*. 123:10:988-992.

Rieger, P.G. and H.J.Knackmuss. 1995. Basic knowledge and perspectives on biodegradation of 2,4,6-trinitrotoluene and related nitroaromatic compounds in contaminated soil. In Spain, J.C., ed. *Biodegradation of nitroaromatic compounds,* p 1-18. New York: Plenum Press,

Rosenblatt, D. H. 1980. Toxicology of explosives and propellants. In Kaye, S. M., ed. *Encyclopedia of explosives and related items.* 9:332-345. Dover, NJ: U.S. Army Armament Research and Development Command.

Ryon, M.G., B.C. Pal, S.S. Talmage, R.H. Ross. 1984. Database assessment of the health and environmental effects of munition production waste products. Final Report. Report no. ORNL-6018. Document no. DE84-016512.

Spain, J.C., G.R. Johnson, R.K. Jain. 2002. Origins of the 2,4-dinitrotoluene pathway. *J. Bacteriol.* 184:4219-4232.

Spanggord, R. J., W. R. Mabey, T. W. Chou, J.H. Smith. 1985. Environmental fate of selected nitroaromatic compounds in the aquatic environment. In Rickert, D. E., ed.. *Chemical industry institute of toxicology series: Toxicology of nitroaromatic compounds,* p 15-34. Washington DC: Hemisphere Publishing Corporation.

Sparks, D.L. 1995. *Environmental soil chemistry*. San Diego: Academic Press.

Thomas, R.G. 1990. Volatization from water. *Handbook of Chemical Property Estimation Methods*. W.J. Lyman, W.F. Reehl, and D.H. Rosenblatt, ed. American Chemical Society, Washington DC, 161:1-50.

Townsend, T.E. and K.F. Myers. 1996. Recent developments in formulating model descriptors for subsurface transformation and sorption of TNT, RDX, and HMX. U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report IRRP-96-1.

Van Duin, A.C. and S.R. Larter. 2001. Molecular dynamics investigation into the adsorption of organic compounds on kaolinite surfaces. *Organic Geochemistry* 32:143-150.

Walsh M.E., T.F. Jenkins, P.G. Thorne. 1995. Laboratory and analytical methods for explosives residues in soil. *Journal of Energetic Materials* 13:357-383.

Wikipedia. 2006. Images downloaded from http://en.wikipedia.org on July 12, 2006.

White, J.C., J.W. Kelsey, P.B. Hatzinger, A. Martin. 1997. Factors affecting sequestration and bioavailability of phenanthrene in soils. *Environmental Toxicology and Chemistry* 16:2040-2045. 1

Xing, B. and J.J. Pignatello. 1998. Competitive sorption Between 1,3-dichlorobenzene or 2,4-dichlorophenol and natural aromatic acids in soil organic matter. *Env. Sci. Technol.* 32:614-619.

Yariv, S. and H. Cross. . 2002. *Organo-clay complexes and interactions.* New York: Marcel Decker Inc.

Young, K. M. 2006. *The effects of aging on the binding and availability of nitroaromatic compounds.* PhD dissertation, University of Notre Dame.

Environmental Fate of Munitions Constituents In Estuary Sediments

Jeffrey W. Talley, Ph.D., P.E

.

1 Introduction

The United States (U.S.) Navy and U.S. Marine Corps traditionally use coastal areas for military exercises and live-fire training. Unexploded or partially exploded ordnance can introduce munitions constituents (MC) into the environment. Advective transport of contaminated sediment from upstream munitions manufacturing facilities can also contaminate an estuary's sediment. Because of the threat of health related effects from these compounds, understanding the fate and transport of these materials once introduced into an estuary is crucial to ensuring protection of public health and the environment.

The primary MC of concern include 2,4,6-trinitrotoluene (TNT); hexahydrol-1,3,5-trinitro-1,3,5-triazene (RDX); octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX); perchlorates; lead metal; and lead compounds, such as the explosive lead azide (PbN_6) and lead styphnate ($PbC_6HN_3O_8{\cdot}H_2O$) (EPA, 2005).

Sources for MC in marine environments include the stock compound manufacturing, assembly, and packing facilities that are located in a watershed. Releases into the environment are transported via advection and sediment load into the estuary. On operational ranges, dissolution from breached unexploded ordnance and partially detonated (low-order detonation) ordnance can also be a source of MC.

Three key processes that describe the fate and transport of MC in marine environments are dissolution kinetics, adsorption to marine sediment, and transformation (via biotic or abiotic processes) of the original compound (Brannon et al., 2005). Although there is an extensive database on the fate and transport parameters of MC in freshwater sediment, there is not much information published on MC in saline water. However, in batch tests, it was reported that RDX and HMX dissolution rates, transformation rates, and adsorption under freshwater and saline conditions are similar (Brannon et al., 2005). As discussed below, in certain tests TNT dissolution rates are slightly lower in saline water.

1.1 Dissolution Rates

Dissolution rates determine how rapidly MC transition from an unexploded or partially exploded munition into solution. Dissolution rates of MC in freshwater have been reported extensively and are shown in Table 1. Dissolution rates of MC increase significantly with temperature (ERDC, 2006). While HMX and RDX dissolution rates are similar in marine and freshwater, TNT rates are lower in saline water (20×10^{-5} vs. 15×10^{-5} mgs^{-1} cm^{-2}) (Brannon et al., 2005).

Table 1: Dissolution Rates of TNT, RDX, and HMX in Freshwater

(ERDC, 2006)

Explosive	Dissolution Rate (20° Celsius) ($mg/s\ cm^2$)
TNT	23.3×10^{-5}
RDX	5.37×10^{-5}
HMX	15.3×10^{-5}

Lead is a stable metal, and adherent films of protective insoluble salts that protect the metal from further corrosion form on lead when exposed to saltwater. Lead solubility is pH dependent and varies from 10 parts per billion (ppb) at pH 8 to 100 ppb at pH 6.5. The dissolved portion tends to form ligands.

Perchlorate is the most soluble of the MC and rapidly partitions into the dissolved phase.

1.2 Adsorption Kinetics

Limited information is available on the adsorption of MC in sediment slurries in saline environments. However, in freshwater systems, shake tests conducted with a variety of MC and soil types provided the information in Table 2. According to Brannon et al. (2005), there are no significant differences between the sorption of HMX, RDX, and TNT in saline and freshwater conditions.

Lead is effectively removed from the water column to the sediment by adsorption to organic matter and clay minerals, precipitation as insoluble salt (the carbonate or sulfate, sulfide), and reaction with hydrous iron and manganese oxide.

Perchlorate does not adsorb to soil. Any perchlorate found in sediment is most likely in the dissolved phase in the pore water.

Table 2: Partition Coefficients for MC and Propellants in Freshwater
(ERDC, 2006)

Compound	CEC (meq/100 g)	TOC (%)	Clay (%)	Kd (L/kg^2)	References
TNT (Sharkley clay)	38.9	0.20	48.7	10	Pennington and Patrick, 1990
TNT (WES silt)	12.4	0.57	7.5	4.5	Myers et al., 1998
RDX (Sharkley clay)	38.9	0.20	48.7	2.73	Price et al., 1998
RDX (WES silt)	12.4	0.57	7.5	0.77	Myers et al., 1998
HMX (Sharkley clay)	38.9	0.20	48.7	19.8	Price, et al., 1998
HMX (WES silt)	12.4	0.57	7.5	1.17	Myers et al., 1998
Perchlorate (Sharkley clay)	38.9	0.20	48.7	NA	Brannon et al., 2004
Perchlorate (Lake Park)	22.3	1.40	17.5	NA	Brannon et al., 2004

Notes:

CEC – Cation Exchange Capacity
Kd – Partition Coefficient between soil and freshwater
L/kg^2 – Liters / Kilogram
meq/100 g – Milliequivelants / 100 grams
NA – Not Applicable or was not observed
TOC – Total Organic Carbon
WES – Waterways Experiment Station

1.3 Transformation

Transformation rates and daughter compounds for all MC are widely reported in freshwater environments (see Section 2.0).

Brannon et al. (2005) conducted a study on three different freshwater sediments that they adjusted to make saline. When comparing the transformation rates under freshwater and saline conditions, they reported that transformation did not vary significantly. Transformation of TNT to 2-amino-4,6-dinitrotoluene (2ADNT) and 4-amino-2,6-dinitrotoluene (4ADNT) typically occurred between 2.8 and 7.3 hours (average pseudo first-order kinetic rate [k] = 0.158 hr^{-1}). Transformation of RDX to Hexahydro-1-mononitroso-3,5-dinitro-1,3,5-triazine (MNX) occurred much slower, with an average k of 0.00037 hr^{-1}. Transformation of HMX to mononitroso-HMX (MN-HMX) was observed in one sediment, but at an even slower rate (k = 0.000093 hr^{-1}).

2 Discussion of Fate and Transport of Individual MC

For any prediction of MC fate, not only is MC loading an important parameter, but parameters such as sediment characteristics, water characteristics, and sediment transport characteristics are necessary as well.

With the exception of Brannon et al. (2005), there is very little research on the fate and transport of MC in estuary environment. However, that study suggests that there is not a significant difference in the physiochemical characteristics of MC in saline and freshwater environments. Each of the MC considered reacts differently in the sediment of an estuary. The following section discusses the fate of individual MC in this unique environment.

2.1 TNT

Adsorption and transformation are the primary processes influencing the fate and transport of TNT in estuarine environments. Volatilization is not an important mechanism for solid TNT due to a high solubility, low Henry's law constant, and low vapor pressure (McGrath, 1995). Dissolution from solid phase TNT is relatively faster than HMX and RDX.

TNT does bind to sediments, but the measured and estimated soil organic carbon adsorption coefficients of 300-1100 indicate that TNT does not strongly partition from surface waters to sediments (Spanggord et al., 1985). It has been shown that sequestration of TNT is highest in soils with high organic carbon content (Pennington et al., 1995).

TNT can undergo transformation via microbiological processes in soil (Walsh et al., 1995). TNT can also be removed by macroalgae (seaweed) via the same metabolic rate demonstrated with terrestrial and freshwater plants (Cruz-Urbine, Cheney, and Rorrer, 2007). Figure 1 illustrates the transformation pathways for TNT in freshwater. The resulting products mirror those reported in salt water by Brannon et al. (2005).

Figure 1: TNT transformation pathways
(Nishino and Spain, 2002)

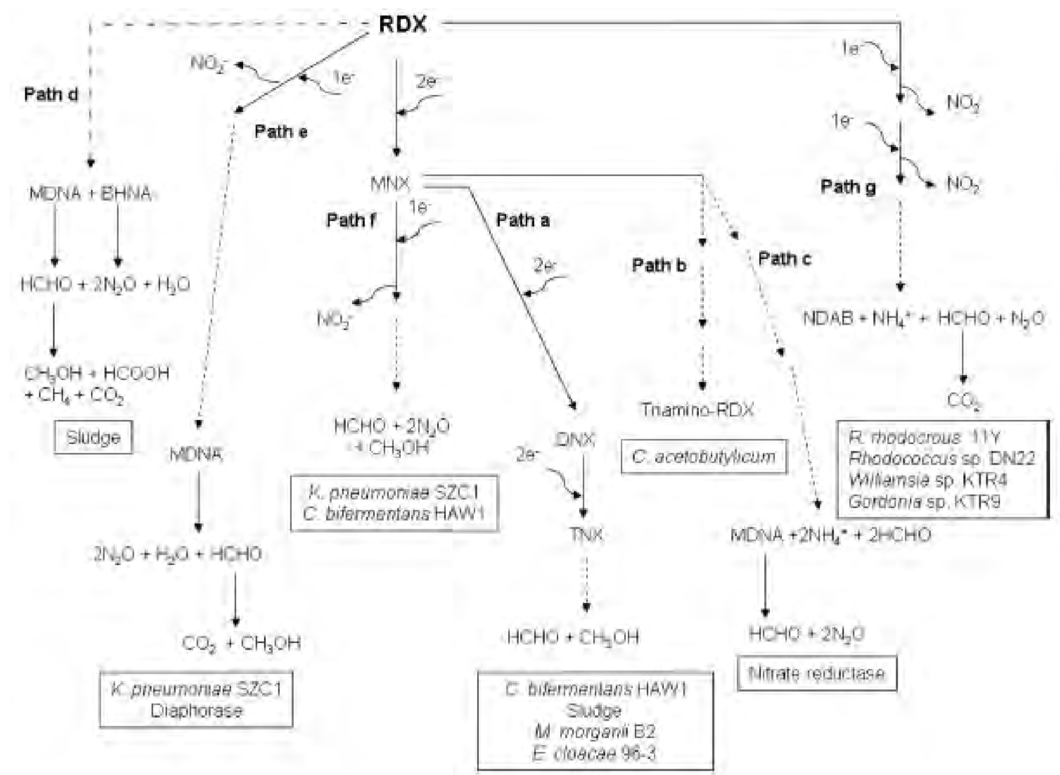
2.2 *RDX*

RDX has a lower vapor pressure than TNT; however, it can exist in both vapor and particulate phases in the atmosphere (Eisenreich, Looney, and Thornton, 1981). The solubility of RDX is also lower than that of TNT; yet it has a higher Henry's law constant. This combination of properties indicates that RDX may partition equally between the atmosphere and surface water; however, volatilization of soluble RDX is a slow transport process (Eisenreich, Looney, and Thornton, 1981; Lyman et al., 1982).

Organic Carbon Absorption Coefficient ($K_{OC)}$ values range from 63.1 to 270 (ATSDR, 1995), indicating medium-to-high mobility in soil and sediment. Experimental data show RDX adsorption to sediment and particulate matter should not be significant (ATSDR, 1995). Although there is no significant adsorption to sediment, adsorption increases with greater clay or organic matter content. As RDX does not adsorb to soils as readily as TNT, RDX shows higher relative mobility than TNT, as observed by Brannon and Myers (1997).

In anaerobic environments, the biotic transformation of RDX is possible. Typically, this is through denitration and reduction and occurs at a much lower rate than for TNT (Brannon and Pennington, 2002). Brannon et al. (2005) did not report any RDX transformation products in their batch experiments of saline environments. However, they postulated that it may be due to short run times or incorrect microorganisms. Although all transformation products are not always observed, Crocker and Indest (2006) postulated the following degradation pathway:

Figure 2: Biodegradation pathway of RDX
(Crocker and Indest, 2006)



Notes:
MDNA: Methylenedintramine
NDAB: 4-nitro-2,4-diazabutanal
DNX: hexahydro-1,3-dinitroso-5-nitro-1,3,5-triazine
TNX: hexahydro-1,3,5-trinitroso-1,3,5-. triazine
BHNA: bis-(hydroxymethyl)nitramine

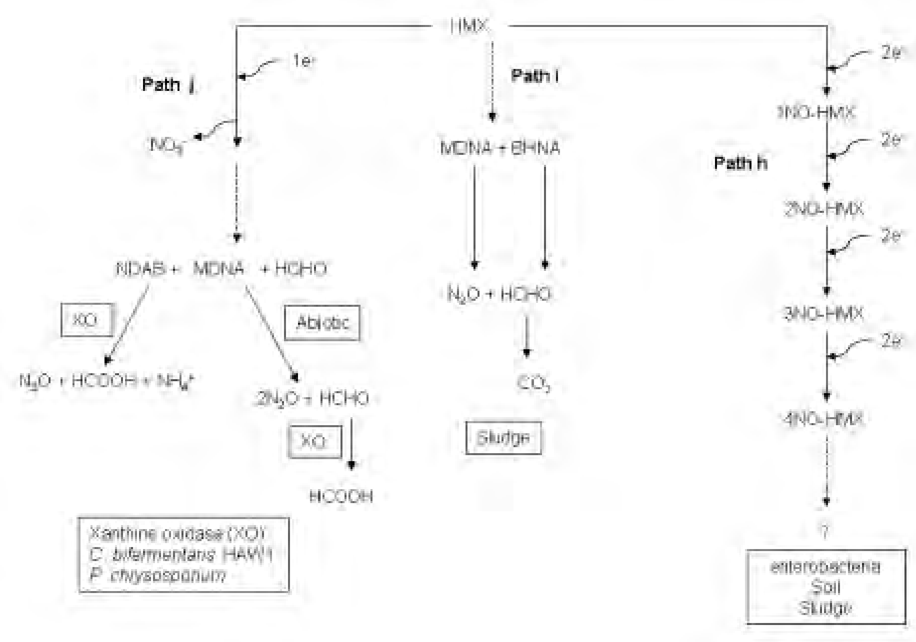
2.3 HMX

HMX has an extremely low vapor pressure and small Henry's law constant, indicating it does not readily volatilize from water.

HMX has a lower solubility and lower disassociation rate than TNT and RDX, suggesting a slow partitioning to the dissolved phase. With similar Kd values to RDX, once HMX is in the dissolved phase, it is less likely to adsorb and is likely to be more mobile than TNT.

HMX is shown to be more biologically recalcitrant than both TNT and RDX. In marine environments, anaerobic microorganisms decreased the HMX concentration by only 17% - 25% (Zhao et al., 2003). A possible degradation pathway is shown in Figure 3.

Figure 3: Biodegradation pathway of HMX
(Crocker and Indest, 2006)



2.4 Perchlorate

Perchlorate is typically found as perchloric acid or ionic salts (e.g., ammonium, sodium, potassium as the cation and perchlorate as the anion).

Perchlorate is extremely soluble, stable, and mobile. Therefore, it is the most likely to reach an estuary environment after being released in the watershed. Very little is known about the interaction of soil/sediment and perchlorate; however, like nitrate, perchlorate may not substantially adsorb onto soils or sediment. This can be surmised from the fact that perchlorate is not likely to serve as a ligand (Cotton and Wilkinson, 1988).

The only reduction paths for perchlorate may be naturally occurring perchlorate reducing bacteria, remediation activities such as ion exchange treatment, or soil oxidation-reduction potential manipulation. Some freshwater plants have been found to uptake perchlorate with their root systems and concentrate it in their tissues.

The fate of perchlorate may be continuous build-up in natural waters, proportional to the amount deposited and movement of the water, with only a small removal term.

2.5 Lead

Lead released to the atmosphere exists primarily as particulates and eventually is removed by wet or dry deposition (ATSDR, 2005). Lead has been reported in sediment cores of lakes in northern Ontario and Quebec, Canada, a far distance from lead release sites. This indicates that long-range transport of lead via the atmosphere may be important (Evans and Rigler, 1985). In contrast, Berndtsson (1993) has reported that local sources of lead (less than 10 kilometers from deposition site) dominate contamination sites. In either case, the transport of lead through the air with final deposition to surface water or soil is an important transport mechanism.

Metallic lead is attacked by water in the presence of oxygen, but if the water contains carbonates and silicates, protective films are formed preventing further attacks. The lead that dissolves tends to form ligands. Lead is effectively removed from the water column to sediment by adsorption to organic matter and clay minerals, precipitation as insoluble salt, and reaction with hydrous iron and manganese oxide. Under most circumstances, adsorption predominates.

The most stable form of lead in natural water is a function of the ions present, the pH, and the reduction-oxidation potential. In oxidizing systems, the least soluble common forms are probably the carbonate, hydroxide, and the hydroxycarbonate. In reduced systems where sulfur is present, PbS is the stable solid. The solubility of lead is 10 ppb above pH 8; below pH 6.5, solubility can approach or exceed 100 ppb. Pb^0 and Pb^{+2} can be oxidatively methylated by naturally occurring compounds such as methyl iodide and glycine betaine. This can result in the dissolution of lead already bound to sediment or particulate matter.

Unlike perchlorate, the migration of lead in sediment is affected by a very large affinity for adsorption at mineral surfaces, formation of organic-lead complexes and chelates with soil organic matter, and electrostatic interaction with soil (ATSDR, 2005). These interactions are strong enough that the accumulation of lead in soil is a function of the rate of deposition with very little transported back to surface water or into groundwater except under acidic conditions.

Sediment microorganisms are able to directly methylate certain inorganic lead compounds. Under appropriate conditions, dissolution due to anaerobic microbial action may be significant in subsurface environments.

3 CONCLUSION

There are very few studies done on the fate and transport of MC in marine and estuary environments. In conclusion, a summary of the fates of the individual contaminants in an estuary, as we can determine them with as of yet limited understanding, follows:

1) TNT quickly disassociates in marine water. Next to perchlorate, it has the highest solubility of all MC. Microbial degradation in sediments is the most likely method of TNT removal. TNT also sorbs to marine sediments, particularly to those with high carbon content. TNT distribution in an estuary environment likely mirrors that of the sediment flow.

2) RDX and HMX are adsorbed less in sediment than TNT and, because of lower solubility and disassociation constants, have limited migration in the dissolved phase. These compounds are often present in the particulate phase and are both relatively (HMX even more so) recalcitrant to biotic transformation; however, further study of the biological degradation of these compounds is necessary.

3) Perchlorate is very soluble and does not readily adsorb to soil. Surface water concentrations grow in conjunction with perchlorate loading unless checked by known perchlorate reducing bacteria. Perchlorate is the most likely to be introduced in the dissolved phase through advective transport from the estuary watershed.

4) Lead has low mobility and extremely high soil affinity. Unless introduced directly, its likely introduction is through the estuary sediment load or deposition. Sediment acts as a filter for particulate lead. Lead distribution in an estuary environment likely mirrors that of the sediment flow.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1995. Toxicological profile for RDX. Public Health Service, U.S. Department of Health and Human Services.

------. 2005. Draft toxicological profile for Lead. Public Health Service, U.S. Department of Health and Human Services.

Berndtsson, R. 1993. Small-scale spatial patterns of bulk atmospheric deposition. *J. Environ Qual* 22:349-360.

Brannon, J.M., C.B. Price, S.L. Yost, C. Hayes, and B. Porter. 2005. Comparison of environmental fate and transport process descriptors of explosives in saline and freshwater systems. *Marine Pollution Bulletin* 50:247-251.

Brannon, J.M. and J.C. Pennington. 2002. Environmental fate and transport process descriptors for explosives. U.S. Army Corps of Engineers Engineer Research and Development Center, ERDC/EL TR-02-10.

Brannon, J.M. and T. E. Myers. 1997. Review of fate and transport processes of explosives. U. S. Army Corps of Engineers, Waterways Eexperiment Station, Technical Report IRRP-97-2.

Brannon, J. M., J. C. Pennington, S. Yost, and C. Hayes. 2004. Fate and transport of explosives. *Battelle Conference on Sustainable Range Management*, January 5-8, 2004, New Orleans, LA.

Cotton, F. A. and G.Wilkinson. 1988. *Advanced inorganic chemistry*, 5th ed., p 745. New York: Wiley.

Crocker, F. and K. Indest. 2006. Biodegradation of the cyclic nitramine explosives RDX, HMX, and CL-20. *Appl. Microbiol. Biotechnol.* 73:274-290.

Cruz-Uribe, O., D.P. Cheney, and G.L. Rorrer. 2007. Comparison of TNT removal from seawater by three marine macroalgae. *Chemosphere* 1469-1474.

Eisenreich, S. J., S. B. Looney, and J. D. Thornton. 1981. Airborne organic contaminants in the Great Lakes ecosystem. *Environ Sci Technol* 15:30-38.

ERDC. See U.S. Army Corps of Engineers.Evans, R. D. and F. H. Rigler. 1985. Long distance transport of anthropogenic lead as measured by lake sediments. *Water Air Soil Pollut* 24: 141-151.

EPA 2005. Handbook on the Management of Munitions Response Actions (Interin Final), Environmental Protection Agency, EPA 505-B-01-001.

Lyman W.J., W.F. Reehl, D.H. Rosenblatt. 1982. *Handbook of chemical property estimation methods: Environmental behavior of organic compounds*. New York, NY: McGraw-Hill Book Company.

McGrath, J.C. 1995. Review of formulations for processes affecting the subsurface transport of explosives. U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report IRRP-95-2 and references therein.

Myers, T. E., J.M. Brannon, J.C. Pennington, D.M. Townsend, W.M. Davis, M.K. Ochman, C.A. Hayes and K.F. Myers. 1998. Laboratory studies of soil sorption/transformation of TNT, RDX, and HMX. U. S. Army Engineer Waterways Experiment Station Technical Report IRRP-98-8.

Nishino, S.F. and J.C. Spain. 2002. Biodegradation, transformation and bioremediation of nitroaromatic compounds. In C.H. Hurst, G.R. Knudsen, M.J. McIlnerney, L.D. Stetzenbach, and M.V. Walter (eds.) *Manual of Environmental Microbiology*, 2nd edition. ASM Press, Washington, DC.

Pennington, J.C., and W.H. Patrick, Jr. 1990. Adsorption and Desorption of 2,4,6-Trinitrotoluene by soils. *J. Env. Qual*. 19:559-567.

Pennington, J.C., C.A. Hayes, K.F. Meyers, M. Ochman. 1995. Fate of 2,4,6-trinitrotoluene in a simulated compost system. *Chemosphere* 30:429-438.

Price, C.B., J.M. Brannon, S.L. Yost. 1998. Transformation of RDX and HMX Under Controlled Eh/pH Conditions. U.S. Army Engineer Waterways Experiment Station. Technical Report IRRP-98-2.

Spanggord, R. J., W.R. Mabey, T.W. Chou, J.H. Smith. 1985. Environmental fate of selected nitroaromatic compounds in the aquatic environment. In Rickert, D. E., ed. ***Chemical industry institute of toxicology series: Toxicology of nitroaromatic compounds,*** p 15-34. Washington, D.C.: Hemisphere Publishing Corporation,.

Walsh M.E., T.F. Jenkins, P.G. Thorne. 1995. Laboratory and analytical methods for explosives residues in soil. *Journal of Energetic Materials* 13:357-383.

U.S. Army Corps of Engineers Engineer Research and Development Center (ERDC). 2006. Distribution and fate of energetics on DoD test and firing ranges: Final report. TR-06-13. Pennington ed.

Zhao, J., C.W. Greer, S. Thiboutot, G. Ampleman, and J. Hawari. 2003. Biodegradation of the nitramine explosives HMX and RDX in cold marine sediment under anaerobic and oligotrophic conditions. *Can. J. Microbiol.* 50:91-94.

APPENDIX G

DEPARTMENT OF DEFENSE SCREENING VALUES

Operational Range Assessment Screening Value Tables

Table 1 - Human Drinking Water Values

MC	CAS #	Screening Value	
		Value (µg/L)	Source
Antimony	7440-36-0	15	EPA RSL Table[a]
Arsenic	7440-38-2	0.045	EPA RSL Table[a]
Barium	7440-39-3	7300	EPA RSL Table[a]
Cadmium	7440-43-9	18	EPA RSL Table[a]
Chromium[1]	7440-47-3	110	EPA RSL Table[a]
Copper	7440-50-8	1500	EPA RSL Table[a]
Lead	7439-92-1	15	Region 6[b]
Manganese	7439-96-5	880	EPA RSL Table[a]
Mercury[2]	7487-94-7	0.63	EPA RSL Table[a]
Molybdenum	7439-98-7	180	EPA RSL Table[a]
Nickel	7440-02-0	730	EPA RSL Table[a]
Silver	7440-22-4	180	EPA RSL Table[a]
Vanadium	7440-62-2	180	EPA RSL Table[a]
Zinc	7440-66-6	11000	EPA RSL Table[a]
HMX	2691-41-0	1800	EPA RSL Table[a]
RDX	121-82-4	0.61	EPA RSL Table[a]
TNT	118-96-7	2.2	EPA RSL Table[a]
1,3,5-TNB	99-35-4	1100	EPA RSL Table[a]
1,3-DNB	99-65-0	3.7	EPA RSL Table[a]
tetryl	479-45-8	150	EPA RSL Table[a]
NB	98-95-3	3.4	EPA RSL Table[a]
2A-4,6-DNT	35572-78-2	73	EPA RSL Table[a]
4A-2,6-DNT	1946-51-0	73	EPA RSL Table[a]
DNT-mixture 2,4/2,6	25321-14-6	.099	EPA RSL Table[a]
2,6-DNT	606-20-2	37	EPA RSL Table[a]
2,4-DNT	121-14-2	73	EPA RSL Table[a]
2-NT (o-)	88-72-2	370	EPA RSL Table[a]
3-NT (m-)	99-08-1	122	Region 6[b]
4-NT (p-)	99-99-0	4.2	EPA RSL Table[a]
Nitroglycerin	55-63-0	3.7	EPA RSL Table[a]
PETN	78-11-5	NA	
Perchlorate	14797-73-0	15	DoD[c]

Notes:
These values are "default" values. Local standards may be more stringent and take precedence.
NA – Not Available (Screening levels were not developed due to the lack of scientific data on the specific constituents.
1 - Screening value is for Total Chromium
2 - Screening value is for Elemental Mercury
Sources:
a - EPA Regional Screening Levels (RSL) table – From "Regional Screening Levels for Chemical Contaminants at Superfund Sites" which is an update for Region 3 RBCs, Region 6 MSSLs, and Region 9 PRGs. From: http://epa-prgs.ornl.gov/chemicals/index.shtml (23 June 2008)
b - Region 6 – Region 6 MSSL Values
c - DoD – The Department of Defense 22 Apr 09 Memo Perchlorate Release Management Policy.

Table 2 – Ecological Freshwater Surface Water System Values

		Freshwater Surface Water		Freshwater Sediment	
MC	**CAS #**	**Value (µg/L)**	**Source**	**Value (mg/kg)**	**Source**
Antimony	7440-36-0	30	EPA Region 3[a]	12	EPA Region 4[d]
Arsenic	7440-38-2	150	EPA NRWQC[2,b]	8.2	EPA OSWER[*,c]
Barium	7440-39-3	3.9	EPA OSWER[c]	20	EPA Region 6[f]
Cadmium	7440-43-9	0.25	EPA NRWQC[2,3,b]	1.2	EPA OSWER[c]
Chromium (VI)	7440-47-3	11	EPA NRWQC[2,b]	81	EPA OSWER[c]
Copper	7440-50-8	9	EPA NRWQC[2,3,b]	34	EPA OSWER[c]
Lead	7439-92-1	2.5	EPA NRWQC[2,3,b]	47	EPA OSWER[c]
Manganese	7439-96-5	80	EPA OSWER[c]	460	Ontario Guidelines[i]
Mercury	22967-92-6	0.77	EPA NRWQC[2,b]	0.15	EPA OSWER[c]
Molybdenum	7439-98-7	240	EPA OSWER[c]	4	D.D.MacDonald et al., 1994[g]
Nickel	7440-02-0	52	EPA NRWQC[2,3,b]	21	EPA OSWER[c]
Silver	7440-22-4	3.2	EPA NRWQC[2,3,b]	2	EPA Region 4[d]
Vanadium	7440-62-2	19	EPA OSWER[c]	50	NOAA Screening Tables[h]
Zinc	7440-66-6	120	EPA NRWQC[2,3,b]	150	EPA OSWER[c]
HMX	2691-41-0	150	EPA Region 3[a]	.0047-.47	EPA Region 4[1,d]
RDX	121-82-4	190	EPA Region 4[d]	.013-1.3	EPA Region 4[1,d]
TNT	118-96-7	90	EPA Region 4[d]	.092-9.2	EPA Region 4[1,d]
1,3,5-TNB	99-35-4	11	EPA Region 4[d]	.0024-.24	EPA Region 4[1,d]
1,3-DNB	99-65-0	20	EPA Region 4[d]	.0067-.67	EPA Region 4[1,d]
tetryl	479-45-8	NA		53.4	Nipper et al., 2002[j] (fine grain sediment)
NB	98-95-3	270	EPA Region 4[d]	0.488	EPA Region 4[d]
2A-4,6-DNT	35572-78-2	20	EPA Region 4[d]	NA	
4A-2,6-DNT	1946-51-0	NA		NA	
2,6-DNT	606-20-2	42	EPA Region 4[d]	0.0206	EPA Region 4[d]
2,4-DNT	121-14-2	44	EPA Region 3[a]	0.0751	EPA Region 4[d]
2-NT (o-)	88-72-2	NA		NA	
3-NT (m-)	99-08-1	750	EPA Region 3[a]	NA	
4-NT (p-)	99-99-0	1900	EPA Region 3[a]	NA	
Nitroglycerin	55-63-0	138	EPA Region 3[a]	NA	
PETN	78-11-5	85000	EPA Region 3[4,a]	NA	
Perchlorate	14797-73-0	9300	Dean et al.[e]	NA	

Notes:
NA – Not Available (Screening levels were not developed due to the lack of scientific data on the specific constituents.
* - Arsenic values for sediment will be compared to background sampling data, if available. The range will not be considered a source of MC migration when the sampling results are less than or equivalent to background concentrations.

1 - These values are dependent on the sediment TOC. The lower bound is for 1% TOC. Upper bound is for 100% TOC. To determine the site specific value, multiply the % TOC by the lower bound. E.g. for TNT in sediment w/ 5% TOC it would be: 0.46 (5*0.092=0.46)
2 - Value applies to dissolved metals
3 - The value is dependent on the hardness of the water, provided value is for a water hardness of 100 mg/L as CaCO3.
4 – For PETN, EPA Region III values came from TNRCC 2001 & 2000, which are documented sources k & l below.

Sources:
a - EPA Region 3, Ecological Risk Assessment Freshwater Screening Benchmarks, March 2007
b - EPA, Office of Water, Office of Science and Technology (4304T), National Recommended Water Quality Criteria, 2006.

c - EPA Office of Solid Waste and Emergency Response Ecotox Thresholds, January 1996
d - EPA Region 4, Ecological Risk Assessment Bulletins – Supplement to RAGS (EPA 2001)
e - Dean, K.E., R.M. Palachek, J.L. Noel, R. Warbritton, J. Aufderheide, and J. Wireman. 2004. Development of Freshwater Water-Quality Criteria for Perchlorate. Environmental Toxicology and Chemistry 23(6):1441-1451.
f - EPA Region 6, Screening Level Ecological Risk Assessment Protocol, Aug 1999.
g – A Review of Environmental Quality Criteria and Guidelines for Priority substances in the Fraser River Basin, Prepared by D.D. MacDonald, MacDonald Environmental Sciences Limited, March 1994
h - NOAA Screening Quick Reference Tables, NOAA HAZMAT Report 99-1, Seattle WA, Coastal Protection and Restoration Division, National Oceanic and Atmospheric Administration, 12 pages. Buchman, M.F., 1999.
i - Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Queen's Printer of Ontario. Persaud, D., R. Jaagumagi, and A. Hayton. 1993.
j - Nipper, M., R.S. Carr, J.M. Biedenbach, R.L. Hooten, and K. Miller. 2002. Toxicological and Chemical Assessment of Ordnance Compounds in Marine Sediments and Porewaters. Marine Pollution Bulletin, 44: 789-806.
k - TNRCC 2001 Guidance for Conducting Ecological Risk Assessment and Remediation Sites in Texas, Toxicology and Risk Assessment Section, December.
l - TNRCC 2000 Texas Surface water Quality Standards, Texas Administrative Code, Title 30, Chapter 307, Effective 17, 2000.

Table 3 – Ecological Marine Surface Water System Values

		Marine Surface Water		Marine Sediment	
MC	**CAS #**	**Value (µg/L)**	**Source**	**Value (mg/kg)**	**Source**
Antimony	7440-36-0	30	Suter and Tsao, 1996[e]	2	NOAA 1990[g]
Arsenic	7440-38-2	36	USEPA, 2004[b]	7.24	MacDonald et al., 2000*[,h]
Barium	7440-39-3	4	Suter and Tsao, 1996[e]	NA	
Cadmium	7440-43-9	8.8	USEPA, 2004[b]	0.68	MacDonald et al., 2000[h]
Chromium (VI)	7440-47-3	50	USEPA, 2004[b]	52.3	MacDonald et al., 2000[h]
Copper	7440-50-8	3.1	USEPA, 2004[b]	18.7	MacDonald et al., 2000[h]
Lead	7439-92-1	8.1	USEPA, 2004[b]	30.2	MacDonald et al., 2000[h]
Manganese	7439-96-5	120	Suter and Tsao, 1996[e]	460	Ontario Guidelines[i]
Mercury	22967-92-6	0.94	USEPA, 2004[b]	0.14	
Molybdenum	7439-98-7	370	Suter and Tsao, 1996[e]	NA	
Nickel	7440-02-0	8.2	USEPA, 2004[b]	15.9	MacDonald et al., 2000[h]
Silver	7440-22-4	1.9	USEPA, 2004[b]	0.73	MacDonald et al., 2000[h]
Vanadium	7440-62-2	20	Suter and Tsao, 1996[e]	NA	
Zinc	7440-66-6	81	USEPA, 2004[b]	124	MacDonald et al., 2000[h]
HMX	2691-41-0	330	Talmage et al., 1999[o]	.0047-.47	EPA Region 4[1,a]
RDX	121-82-4	5000	Nipper et al., 2001[k]	.013-1.3	EPA Region 4[1,a]
TNT	118-96-7	180	Nipper et al., 2001[k]	.092-9.2	EPA Region 4[1,a]
1,3,5-TNB	99-35-4	25	Nipper et al., 2001[k]	.0024-.24	EPA Region 4[1,a]
1,3-DNB	99-65-0	180	Nipper et al., 2001[k]	.0067-.67	EPA Region 4[1,a]
tetryl	479-45-8			53.4	Nipper et al., 2002[l] (fine grain sediment)
NB	98-95-3	66.8	USEPA, 2002[c]	27	Talmage and Opresko, 1995[j]
2A-4,6-DNT	35572-78-2	1480	TNRCC, 2001[m] and TNRCC, 2000[n]	NA	
4A-2,6-DNT	1946-51-0	NA	NA	NA	
2,6-DNT	606-20-2	1000	Nipper et al., 2001[k]	0.55	Nipper et al., 2002[l]
2,4-DNT	121-14-2	480	Nipper et al., 2001[k]	0.23	Talmage and Opresko, 1995[j]
2-NT (o-)	88-72-2	NA	NA	NA	
3-NT (m-)	99-08-1	NA	NA	NA	
4-NT (p-)	99-99-0	NA	NA	NA	
Nitroglycerin	55-63-0	138	TNRCC, 2001[m] and TNRCC, 2000[n]	NA	
PETN	78-11-5	85000	EPA Region 3[2,d]	NA	
Perchlorate	14797-73-0	9300	Dean et al., 2004[f]	NA	

Notes:

NA – Not Available (Screening levels were not developed due to the lack of scientific data on the specific constituents.
* - Arsenic values for sediment will be compared to background sampling data, if available. The range will not be considered a source of MC migration when the sampling results are less than or equivalent to background concentrations.

1 - These values are dependent on the sediment TOC. The lower bound is for 1% TOC. Upper bound is for 100% TOC. To determine the site specific value, multiply the % TOC by the lower bound. (e.g. for TNT in sediment w/ 5% TOC it would be: 0.46)(5*0.092=0.46)
2 - EPA Region III for PETN marine water refers to US EPA Region 3's Freshwater Screening Benchmark table for a value. These values came from TNRCC 2001 & 2000, which are documented sources m & n below.

Sources:

a - EPA Region 4, Ecological Risk Assessment Bulletins - Supplement to RAGS (EPA 2001)
b – EPA – USEPA 2004 National Recommended Water Quality Criteria Office of Water and Office of Science and Technology.
c – EPA – USEPA 2002 Ecological Risk Assessment Bulletin 2/11/2002. Waste Management Division, Freshwater Surface Screening Values for Hazardous Waste Sites, February.
d - EPA Region 3, Ecological Risk Assessment Freshwater Screening Benchmarks, March 2007
e – Suter and Tsao, 1996 Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 196 Revision. ES/ER/Tm-96/R2.
f – Dean, K.E., R.M. Palachek, J.L. Noel, R. Warbritton, J. Aufderheide, and J. Wireman. 2004. Development of Freshwater Water-Quality Criteria for Perchlorate. Environmental Toxicology and Chemistry 23(6):1441-1451.
g - The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program. NOAA Technical Memorandum NOS OMA 52. Long, E.R. and L.G. Morgan. 1990.
h - MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology, 39: 20-31.
i - Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Queen's Printer of Ontario. Persaud, D., R. Jaagumagi, and A. Hayton. 1993.
j - Talmage, S.S., and D.M. Opresko. 1995. Draft Ecological Criteria Documents for Explosives, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
k – Nipper, M., R.S. Carr, J.M. Biedenbach, R.L. Hooten, K. Miller, and S. Saepoff, 2001. Development of Marine Toxicity Data for Ordnance Compounds, Archives of Environmental Contamination and Toxicology, 41:308-31.
l - Nipper, M., R.S. Carr, J.M. Biedenbach, R.L. Hooten, and K. Miller. 2002. Toxicological and Chemical Assessment of Ordnance Compounds in Marine Sediments and Porewaters. Marine Pollution Bulletin, 44: 789-806.
m – TNRCC 2001 Guidance for Conducting Ecological Risk Assessment and Remediation Sites in Texas, Toxicology and Risk Assessment Section, December.
n – TNRCC 2000 Texas Surface water Quality Standards, Texas Administrative Code, Title 30, Chapter 307, Effective 17, 2000.
o – Talmage, S.S., D.M. Opresko, C.J. Maxwell, J.E. Welsh, M. Cretelia, P.H. Reno, and F.B. Daniel. 1999. Nitroaromatic munition compounds: Environmental effects and screening values. Reviews in Environmental Contamination and Toxicology, 161: 1-156.

APPENDIX H

REFERENCES

REFERENCES

10 U.S.C. § 101(e) (3) (2006).

Brown and Root Environmental. 1996. Report documenting the Health Consultation for the Air Pathway at Sierra Army Depot (SIAD), CA.

California Office of Scientific Affairs, Department of Toxic Substances Control. 1993. *CalTOX™, A Multimedia Total Exposure Model for Hazardous-Waste Sites: User's Guide.* Prepared by The University of California, Davis in cooperation with Lawrence Livermore National Laboratory.

Defense Ammunition Center. Munitions Items Disposition Action System (MIDAS). https://midas.dac.army.mil/.

Department of Defense (DoD) Directive 3200.15. January 2003. *Sustainment of Ranges and Operating Areas (OPAREAS).*

------ May 2004. Directive 4715.11 [4715.12]. *Environmental and Explosives Safety Management on Operational Ranges within the United States [Outside the United States].*

------. November 2005. Instruction 4715.14. *Operational Range Assessments.*

------. March 2006. *Perchlorate Handbook.*

Executive Order (EO) 12580. January 1987. *Superfund Implementation*.

McCuen, Richard H. 1998. *Hydrologic Analysis and Design,* second edition. Prentice Hall.

Mission-Capable Ranges, Training Range Sustainment Planning and Training Range Inventory FY 2006 Update, pursuant to Fiscal Year 2003 National Defense Authorization Act Section 366 Information Request (366 Report)

Munitions Action Plan (Approved April 2002)

National Defense Authorization Act (NDAA) for FY 2003, Section 2811 and Amended FY 2006 Section 2822 (http://www.defenselink.mil/dodgc/olc/docs/PL107-314.pdfhttp://www.cfr.org/publication/9815/national_defense_authorization_act_2006.html)

------. FY 2004, Section 320

Office of the Under Secretary of Defense Memorandum. 15 August 2006. DoD-Regulator Interactions for Operational Range Assessments.

Ordnance Data (ORDDATA) II. Series on compact disk. Enhanced International Deminer's Guide to UXO Identification, Recovery and Disposal; Version 1.0, 1999.

Senior Readiness Oversight Council (SROC) Sustainable Range Action Plan. November 2000.

Untied States Air Force. Edwards Air Force Base. Undated. *Photo.*

United States Army Environmental Center (AEC). United States Army Defense Ammunition Center. United States Army Technical Center for Explosives Safety. July 2000. Study of Ammunition Dud and Low Order Detonation Rates.

------. July 2001. *Phase II Study of Ammunition Dud and Low Order Detonation Rates*.

U.S. Army Corps of Engineers, Engineer Research and Development Center. Characterization of Explosives Contamination at Military Firing Ranges. July 2001.

U.S. Army Corps of Engineers. Engineer Research and Development Center. Cold Regions Research and Engineering Laboratory. June 2002. *Guide for Characterization of Sites Contaminated with Energetic Materials.* ERDC/CRREL TR-02-1.

U.S. Army Corps of Engineers. Identity and Distribution of Residues of Energetic Compounds at Military Live-Fire Training Ranges. November 2005

United States Department of Agriculture—Agriculture Research Service. 2003. *User's Guide—Revised Universal Soil Loss Equation, Version 2*. Available at http://fargo.nserl.purdue.edu/rusle2_dataweb/userguide/RUSLE2-2-3-03.pdf

United States Marine Corps Order 11011.22a. November 1987. *Encroachment Control*.

------. 2004. Non Combat Expenditure Allocation (NCEA).

------. April 11, 2006. *Perchlorate Sampling and Management Policy.*