UNCLASSIFIED

FINAL

REMEDIAL INVESTIGATION / FEASIBILITY STUDY REPORT

NDNODS Fort Tuthill Small Arms Range North AEDB-R Site ID AZHQ-005-R-01

Prepared for:

Army National Guard

Contracting Agency:

U.S. Army Corps of Engineers, Baltimore District

Contract No. W912DR-15-D-0020
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Technical Review Signature Sheet

Project Name:	**Remedial Investigation/Feasibility Study NDNODS Fort Tuthill Small Arms Range North**
Site Location:	**Coconino County, Arizona**
Report Title:	**Remedial Investigation/Feasibility Study Report for NDNODS Fort Tuthill Small Arms Range North, Coconino County, Arizona**
Prepared For:	**Army National Guard**
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Executive Summary

ES.1 BACKGROUND

ES.1.1 INTRODUCTION

ES.1.1.1 The United States (U.S.) Army Corps of Engineers (USACE) conducted the field portion of a Remedial Investigation (RI) at the Fort Tuthill Small Arms Range North, Coconino County, Arizona, between 28 September 2020 and 16 November 2020. This is a Non-Department of Defense (DoD), Non-Operational Defense Site (NDNODS) identified by Army Environmental Database Restoration Number AZHQ-005-R-01. The remedial investigation was conducted in general accordance with the Performance Work Statement (PWS) dated 22 March 2019; and the objectives and goals presented in the approved Uniform Federal Policy – Quality Assurance Project Plan (UFP-QAPP) dated 24 September 2020; and performed in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Defense Environmental Restoration Program (DERP) statute (10 U.S. Code [U.S.C.] 2701, et seq.), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations Part 300), and the Military Munitions Response Program (MMRP), as administered by the USACE. This RI/Feasibility Study (FS) Report has been prepared by Parsons for the USACE Baltimore District under the Army National Guard (ARNG) Contract No. W912DR-15-D-0020, Delivery Order No. W912DR19F0538.

ES.1.1.2 The primary objective and purpose of this RI/FS was to further assess the potential presence of munitions and explosives of concern (MEC) and munitions constituents (MC) contamination within the Munitions Response Site (MRS) based on new information identified since the conduct of the 2012 Site Inspection (SI) and to determine the nature and extent of contamination, if present. Additionally, an assessment to determine if MEC or MC presents an unacceptable risk and, if so, development and evaluation of potential remedial alternatives for the NDNODS Fort Tuthill Small Arms Range North MRS was conducted.

ES.1.1.3 In support of these goals, surface and subsurface anomaly data collection and intrusive investigations were implemented. The MC sampling criteria outlined in the Final UFP-QAPP were not met; due to the absence of one or more identifiable HUAs; however, four surface soil samples were collected and analyzed for explosives at locations where munitions debris (MD) was recovered.

ES.1.1.4 The field investigation was conducted under a work plan (the UFP-QAPP) reviewed and approved by the Systematic Planning Process (SPP) Team, which included representatives from the ARNG, Arizona Army National Guard (AZARNG), USACE Sacramento District (CESPK), the Arizona Department of Environmental Quality (AZDEQ), UXO Pro, Coconino County Parks and Recreation (CCPR), and Parsons.

ES.1.2 SITE DESCRIPTION

ES.1.2.1 The NDNODS Fort Tuthill Small Arms Range North MRS is located approximately 5 miles south of Flagstaff, Coconino County, Arizona (**Figure 2.1**). The RI investigation area includes the original small arms range and associated range safety fan, a north-south oriented partially coincident 2.36-inch bazooka rocket range safety fan, and an east-west oriented potential 2.36-inch bazooka rocket range safety fan all comprising a combined 100-acre footprint. The property is owned and operated by Coconino County as Fort Tuthill County Park and is open to the public. The investigation area also includes portions of the Fort Tuthill Luke Air Force Base Recreational Area, which is a DoD cardholder lodge and recreation area. The investigation area is characterized by gently rolling terrain with elevations ranging from approximately 6,965 feet to 7,010 feet above mean sea level (msl). Vegetation within the investigation area consists of dense to sparse stands of pine-fir conifer forest with grassland (Weston, 2011). A single intermittent stream runs through the center of the MRS and no other surface water bodies are present.

ES.1.2.2 The NDNODS Fort Tuthill Small Arms Range North MRS was originally identified as a 3.18-acre small arms and adjacent artillery range. The small arms range was used from 1928 through 1955 for training with .30 and .50 caliber water-cooled machine guns and Browning Automatic Rifles (.30 caliber). Firing at the range was documented from the northeast to the southwest into an impact berm. Exhibits at the Fort Tuthill Museum list

weapons used at Fort Tuthill as .30 and .50 caliber machine guns, mortars, bazookas (2.36-inch rockets), recoilless rifles, and grenades. However, historical documents regarding the NDNODS Fort Tuthill Artillery Range North MRS indicate that grenades, bazookas (2.36-inch rockets), mortars, and artillery were not associated with the small arms range since other dedicated training ranges for their usage were present within Fort Tuthill.

ES.2 CHARACTERIZATION OF MUNITIONS AND EXPLOSIVES OF CONCERN

ES.2.1 Characterization of the MRS for potential MEC presence consisted of a series of steps beginning with gathering digital geophysical mapping (DGM) survey data on transects strategically spaced across the MRS. The DGM data were used to identify geophysical subsurface anomalies and document their horizontal distribution. This information was then used to differentiate between high anomaly density (HD) and low anomaly density (LD) areas within the NDNODS Fort Tuthill Small Arms Range North MRS. Confirmation of whether or not an HD area represented a potential high-use area (HUA) (i.e., an area contaminated with MEC or a significant amount of MD), and determination of the vertical extent of MEC contamination was then accomplished through the intrusive investigation of anomalies identified during the DGM survey of twelve 0.25-acre grids positioned based on the anomalies density extrapolated from transect mapping. The combined anomaly density information and intrusive results were then used to differentiate between HUAs, low-use areas (LUAs) and no evidence of use (NEU) areas within the MRS.

ES.2.2 Although several HD areas were identified within the MRS, none of them were designated as HUAs based upon the low occurrence of MD found during the RI. The RI identified the entire 100-acre investigation area to be an LUA. No MEC items were discovered during the RI. Historically, one high explosive (HE) MEC item consisting of a 2.36-inch bazooka rocket was identified in 2017. Additionally, one practice rocket was reported in 2000. Isolated MD from 57mm HE recoilless rifle rounds and 60mm HE mortars were found during the RI but were concluded to be the result of a few discrete training demonstrations as opposed to frequent usage.

ES.2.3 Within the NDNODS Fort Tuthill Small Arms Range North MRS, nearly 1000 anomalies were intrusively investigated consisting of 736 from seven HD area grids and 264 from five LD area grids. Of this total, 52 identified anomalies were deemed inaccessible (i.e., under boulders) and 33 duplicate anomalies shared with another anomaly. All eight MD items were covered from depths of less than 25 cm (10 inches) below ground surface (bgs).

ES.3 CHARACTERIZATION OF MUNITIONS CONSTITUENTS

To complete the characterization of MC at the NDNODS Fort Tuthill Small Arms Range North MRS, surface soil samples were collected from the four grids within the investigation area displaying MD presence. Although no HUAs were identified, soil samples were collected from these four grids (grids 1, 2, 5, and 7). Samples were collected using incremental sampling methodology (ISM) and analyzed for explosives only. Ten background samples, collected before confirmation that biased sampling criteria were not met, were collected from predesignated locations and analyzed for both selected munitions composition metals as well as explosives (to confirm background location). Based on the results of the RI sampling, no MC contamination was identified at the NDNODS Fort Tuthill Small Arms Range North MRS.

ES.4 MUNITIONS AND EXPLOSIVES OF CONCERN RISK ASSESSMENT

MEC Risk Management Methodology (RMM) was applied to the NDNODS Fort Tuthill Small Arms Range North MRS investigation area in accordance with the interim guidance document *Trial Period for Risk Management Methodology at Formerly Used Defense Sites Military Munitions Response Program Projects* (USACE, 2017). The RMM was applied separately to two areas within the MRS and a separate set of RMM Matrices were created for each area. The “Focused Area” represents the area of the MRS that encompasses the locations of historically reported 2.36-inch rockets and the locations of MD indicative of MEC in the RI. The “Remainder of MRS” represents the 75-acre balance of the MRS. Based on the RI data, the potential exists for receptors to be exposed to unacceptable explosive hazards within both areas of the NDNODS Fort Tuthill Small Arms Range North MRS. .

ES.5 MUNITIONS CONSTITUENTS RISK ASSESSMENT

Although the MC sampling criteria were not met during this RI due to the absence of one or more identifiable HUAs, four samples were collected and analyzed for explosives to provide additional confirmation of absence of MC contamination within the MRS. Given that no explosives were detected, no chemicals of potential concern (COPCs) are present. Therefore, all exposure pathways for MC are incomplete and human health and ecological risk assessments were not conducted.

ES.6 RI CONCLUSIONS AND RECOMMENDATIONS

ES.6.1 The results of this RI and the assessments of MEC hazards indicate that the MEC contamination identified at the NDNODS Fort Tuthill Small Arms Range North MRS potentially poses an unacceptable risk from explosive hazards to current and future human receptors. No MC risks to human health or the environment were identified due to the absence of an MC contaminant source (MEC or significant MD) and lack of detectable explosive constituents in biased soil samples collected from within the MRS. As such, a risk management decision is recommended to restrict remedial actions to addressing MEC hazards only.

ES.6.2 The presence of MEC hazards negates the potential acceptability of the "no-action" response alternative. Therefore, conduct of an FS was warranted to evaluate viable response actions that could be implemented to address the MEC contamination and associated hazards/risks that have been identified at the NDNODS Fort Tuthill Small Arms Range North MRS. The MEC and MC data collected during the RI were determined to be sufficient to fully characterize the MRS, to identify and evaluate any associated potential MEC hazards or MC risks, and to fully support the FS. The next step will be to prepare a Proposed Plan to convey this finding to the public, followed by a Decision Document to formally memorialize the selected remedy at this MRS.

ES.7 FEASIBILITY STUDY SUMMARY

ES.7.1 OVERVIEW

ES.7.1.1 The objectives of the FS are to ensure that appropriate remedial alternatives are developed and evaluated for the MRS acreage that is recommended for continuance to the FS phase. To meet these objectives, the scope of this FS includes the following:

- Summarizing site characteristics;
- Developing the remedial action objective (RAO);
- Developing, screening, and analyzing remedial alternatives;
- Identifying general response actions and remedial alternatives that address the RAO; and
- Conducting a detailed analysis of the identified remedial alternatives according to the standard U.S. Environmental Protection Agency (USEPA) evaluation criteria.

ES.7.1.2 Remedial alternatives were developed for the primary contaminant (MEC) identified at the NDNODS Fort Tuthill Small Arms Range North MRS. Since there are no risks or hazards to human health resulting from exposure to MC, a risk management decision is recommended to restrict remedial actions to addressing risk from MEC risk only. As such, no RAO or response actions for MC have been developed. The site-specific RAO, found in **Table 2.3**, was developed to address MEC risks based on the current conditions, the explosive safety hazards, and the risks to current and potential future human receptors identified during the RI. The RAO consists of reducing risks resulting from human exposure to unexploded ordnance (UXO) on the surface and in the subsurface soil within the MRS consistent with the area-specific vertical and horizontal RI MEC and MD distribution findings.

ES.7.1.3 A range of remedial technologies were evaluated. Technologies considered viable were assembled into remedial alternatives which were screened based upon effectiveness, implementability, and cost. Remedial alternatives were analyzed in detail with respect to nine evaluation criteria:

1. Overall protection of human health and the environment;
2. Compliance with Applicable or Relevant and Appropriate Requirements (ARARs);
3. Long-term effectiveness and permanence.
4. Reduction of toxicity, mobility, or volume (TMV) through treatment;
5. Short-term effectiveness;
6. Implementability;
7. Cost;
8. State Acceptance; and
9. Community Acceptance – will be evaluated after the public review period.

ES.7.1.4 The comparative analysis of alternatives was conducted using the current conceptual site model (CSM), which is based on the present state of knowledge concerning contamination and both current and reasonably anticipated future land use. The detailed analysis of remedial alternatives is summarized in **Table ES.1** and a brief description of each alternative is provided below.

ES.7.2 REMEDIAL ALTERNATIVES

ES.7.2.1 The remedial alternatives developed to address MEC at the NDNODS Fort Tuthill Small Arms Range North MRS are as follows:

- Alternative 1: No Action
- Alternative 2: Public Education and Warning Signs - land use controls (LUCs)
- Alternative 3: Complete Surface MEC Removal and LUCs
- Alternative 4: Focused Surface and Subsurface MEC Removal and LUCs
- Alternative 5: Complete Surface and Subsurface MEC Removal (Unrestricted Use/Unlimited Exposure) [UU/UE]

ES.7.2.2 The detailed analysis of remedial alternatives for MEC (**Table ES.1**) indicates that Alternatives 4 and 5 would be effective at addressing potential MEC risk at the NDNODS Fort Tuthill Small Arms Range North MRS. The final alternative selection will involve a trade-off analysis with input from stakeholders and the public.

ES.7.3 CONCLUSIONS

Based on the analyses of remedial alternatives conducted in this FS, a Proposed Plan (PP) will be developed to recommend a preferred alternative for implementation.

Table ES.1 Comparison of Remedial Alternatives

CERCLA Evaluation Criteria	Alternative 1 No Action	Alternative 2 LUCs	Alternative 3 Surface MEC Removal with LUCs	Alternative 4 Focused Surface and Subsurface MEC Removal and LUCS	Alternative 5 Complete Surface and Subsurface MEC Removal
Protective of Human Health and the Environment	No	Focused Area – No No change in Decision Logic to Assess Risk (remains Unacceptable) Remainder of MRS - Yes Change in Decision Logic to Assess Risk (Unacceptable to Acceptable)	Focused Area – No Not protective of human health because does not decrease amount of MEC in subsurface and future construction/development involving intrusive activities planned for the area. Remainder of MRS - Yes Change in Decision Logic to Assess Risk (Unacceptable to Acceptable)	Yes Change in Decision Logic to Assess Risk (Unacceptable to Acceptable	Yes Change in Decision Logic to Assess Risk (Unacceptable to Acceptable)
Complies with Applicable or Relevant and Appropriate Requirements	Yes	Yes	Yes	Yes	Yes
Effective and Permanent	No	Medium	High	High	Highest
Reduces Toxicity, Mobility, or Volume through Treatment	None (no treatment)	None (no treatment)	Reduction in volume of MEC on ground surface	Reduction in volume of MEC on ground surface and in subsurface in 25-acre “focused” area	Reduction in volume of MEC on ground surface and in subsurface
Short-Term Effectiveness	No short-term hazards to workers and surrounding area	Some short-term hazards to workers and surrounding area	Significant short-term hazards to workers and surrounding area	Greatest short-term hazards to workers and surrounding area	Greatest short-term hazards to workers and surrounding area
Implementable	Readily Implementable	Readily Implementable	Readily Implementable	Readily Implementable	Readily Implementable
State Acceptance		To be determined during preparation of the Proposed Plan and Decision Document			
Community Acceptance		To be determined during preparation of the Proposed Plan and Decision Document			
Cost (1)	$0	$507,195	$1,830,128	$1,847,912	$4,984,654

(1) Costs shown are based on alternative implementation duration estimates with recurring costs based on 30-year planning horizons specified in the RI/FS Guidance (USEPA, 1988) for the purposes of evaluating and comparing alternatives with a 20% contingency reported as a Total Present Value (TPV). The TPV is based on a discount rate of 7 percent. Details of the cost estimates and the development of the TPVs are provided in Appendix J.

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Acronyms and Abbreviations

APA	anomalies per acre
APP	Accident Prevention Plan
ARAR	applicable or relevant and appropriate requirements
ARNG	Army National Guard
AZARNG	Arizona Army National Guard
AZDEQ	Arizona Department of Environmental Quality
AZGFD	Arizona Game and Fish Department
bgs	below ground surface
BIP	blow-in-place
CA	corrective action
CCPR	Coconino County Parks and Recreation
CD	compact disc
CENAB	U.S. Army Corps of Engineers, Baltimore District
CESPK	U.S. Army Corps of Engineers, Sacramento District
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CHE	CWM Hazard Evaluation
cm	centimeters
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
CPF	Contamination Pathway Factor
CSM	conceptual site model
CWM	Chemical Warfare Materiel
DAGCAP	DoD Advanced Geophysical Classification Accreditation Program
DD	Decision Document
DDESB	DoD Explosives Safety Board
DERP	Defense Environmental Restoration Program
DGM	digital geophysical mapping
DID	data item description
DoD	Department of Defense
DQI	data quality indicator
DQO	data quality objective
DUA	data usability assessment
EHE	Explosive Hazard Evaluation
EM	Engineer Manual
EOD	Explosive Ordnance Disposal
EP	Engineering Pamphlet
EPA	Environmental Protection Agency
EPP	Environmental Protection Plan
ER	Engineer Regulation
ESP	Explosives Site Plan
EZ	exclusion zone
FCR	field change request
FRTR	Federal Remediation Technologies Roundtable
FS	Feasibility Study
ft	feet
FUDS	formerly used defense site

Acronyms and Abbreviations (*continued*)

GIS	geographic information system
GPS	global positioning system
GRA	General Response Actions
GSV	geophysical system verification
H	high
HD	high anomaly density
HE	high explosive
HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HPLC	High-performance liquid chromatography
HRR	Historical Records Review
HUA	high use area
In	inches
ISO	industry standard object
ISM	Incremental Sampling Method
ITRC	Interstate Technology & Regulatory Council
IVS	instrument verification strip
L	low
lb	pounds
LD	low anomaly density
LOD	limit of detection
LOQ	limit of quantitation
LUA	low use area
LUC	Land Use Controls
M	medium
MC	munitions constituents
MD	munitions debris
MDAS	material documented as safe
MEC	munitions and explosives of concern
MGFD	munition with the greatest fragmentation distance
MMRP	Military Munitions Response Program
MPC	measurement performance criteria
MPF	Migration Pathway Factor
MPPEH	material potentially presenting an explosive hazard
MPV	man portable vector
MQO	measurement quality objective
MRS	munitions response site
MRSPP	Munitions Response Site Prioritization Protocol
MS/MSD	matrix spike\ matrix spike duplicate
MSD	minimum separation distance
mV	millivolts
NA	not applicable
NCP	National Contingency Plan
NDNODS	Non-DoD Non-Operational Defense Site
NEU	no evidence of use (area)
NFA	No further action
NMRD	non-munitions-related debris
NPS	National Park Service

Acronyms and Abbreviations *(continued)*

NRHP	National Register of Historic Places
OD	other debris
OESS	Ordnance and Explosives Safety Specialist
OSWER	Office of Solid Waste and Emergency Response
PA	Preliminary Assessment
PARCC	Precision, Accuracy, Representativeness, Comparability, and Completeness
PDT	project delivery team
PHSM	Project Health and Safety Manager
PM	Project Manager
PP	Proposed Plan
PRG	preliminary remediation goals
PSL	project screening level
PWS	performance work statement
QA	quality assurance
QAPP	Quality Assurance Project Plan
QASP	Quality Assurance Surveillance Plan
QC	quality control
QSM	Quality Systems Manual
RAO	Remedial Action Objective
RAWP	Risk Assessment Work Plan
RCA	root cause analysis
RCRA	Resource Conservation and Recovery Act
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
RF	Receptor Factor
RI	Remedial Investigation
ROE	right-of-entry
RL	reporting limit
RMM	risk management method
RPD	relative percent difference
RRD	range-related debris
RSD	relative standard deviation
RSL	Regional Screening Levels
RTK	real-time kinematic
RTS	Robotic Total Station
SI	Site Inspection
SOP	standard operating procedure
SPP	systematic planning process
SU	sampling unit
SUXOS	Senior UXO Supervisor
TBC	to be considered
TMV	toxicity, mobility, or volume through treatment
TO	Task Order
TOI	target of interest
TPP	Technical Project Planning
TPV	total present value
UFP	Uniform Federal Policy
U.S.	United States

Acronyms and Abbreviations *(continued)*

USACE	U.S. Army Corps of Engineers
U.S.C.	U.S. Code
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
UU/UE	unlimited use/unlimited exposure
UXO	unexploded ordnance
UXOQCS	UXO Quality Control Specialist
UXOSO	UXO Safety Officer
VSP	Visual Sample Plan

1.0 Introduction

1.1 PROJECT AUTHORIZATION

1.1.1 This Remedial Investigation (RI)/Feasibility Study (FS) report has been prepared by Parsons to support the long-term management of the National Guard Bureau, Non-Department of Defense (DoD), Non-Operational Defense Site (NDNODS) Fort Tuthill Small Arms Range North Munitions Response Site (MRS), Site ID AZHQ-005-R-01. This work is being conducted for the U.S. Army Corps of Engineers (USACE), Baltimore District (CENAB) under Contract No. W912DR-15-D-0020, Delivery Order No. W912DR19F0538. This project is being executed by Parsons; under this delivery order, Parsons is responsible for fully executing the RI and related tasks at the Fort Tuthill Small Arms Range North MRS.

1.1.2 Based on the discovery of an explosive-filled MEC (2.36-inch bazooka rocket) during the October 2017 construction activities within the MRS, the Army National Guard (ARNG) determined an RI should be conducted at the Fort Tuthill small arms range in Arizona under the Military Munitions Response Program (MMRP) Munitions Response Services. The RI was conducted in general accordance with the performance work statement (PWS) dated 22 March 2019; and the objectives and goals presented in the approved Uniform Federal Policy – Quality Assurance Project Plan (UFP-QAPP) and performed in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Defense Environmental Restoration Program (DERP) statute (10 U.S. Code [U.S.C.] 2701, et seq.), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations Part 300), and the Military Munitions Response Program (MMRP), as administered by the USACE.

1.2 PROJECT PURPOSE AND SCOPE

1.2.1 The purpose of this project was to perform a RI/FS followed by a Proposed Plan (PP) and Decision Document (DD) for the NDNODS Fort Tuthill Small Arms Range North MRS, Coconino County, Arizona. This RI/FS report presents a detailed discussion of the assessment of both the presence or absence and nature and extent of munitions and explosives of concern (MEC) and munitions constituents (MC) and an evaluation of the potential hazards and risks to human health and the environment. The overall goal of this process was to provide sufficient data to facilitate the evaluation of potential future remedial action, as warranted.

1.2.2 In support of these goals, subsurface anomaly data collection and intrusive investigations were conducted at the NDNODS Fort Tuthill Small Arms Range North MRS. Biased surface soil samples were also collected and analyzed for MC (explosives). The information collected during the RI was also used to complete the Munitions Response Site Prioritization Protocol (MRSPP) tables for the MRS, to assess the need to evaluate remedial alternatives in an FS and support informed risk management decisions for future remedial decisions. Project stakeholders, including ARNG, Arizona Army National Guard (AZARNG), USACE Sacramento District (CESPK), the Arizona Department of Environmental Quality (AZDEQ), Coconino County Parks and Recreation (CCPR), and Parsons helped develop the project approach during two Systematic Planning Process (SPP) meetings, held on 30 January 2020 and 10 September 2020, and subsequently accepted the UFP-QAPP (Parsons, 2020, Appendix K).

1.3 REMEDIAL INVESTIGATION/FEASIBILITY STUDY REPORT ORGANIZATION

Organization of this RI/FS Report follows requirements identified in Data Item Description (DID) WERS-010.01 (USACE, 2012) and Engineering Pamphlet (EP) 1110-1-18, Military Munitions Response Process for RI Reports (USACE, 2006). Chapters include:

- Executive Summary;
- Chapter 1: Introduction;
- Chapter 2: Munitions Response Site Description;

- Chapter 3: Project Technical Approach;
- Chapter 4: Data Quality Assessment;
- Chapter 5: Remedial Investigation Results;
- Chapter 6: Contaminant Fate and Transport;
- Chapter 7: Baseline Risk Assessment;
- Chapter 8: Summary of Remedial Investigation Results & Munitions Response Site Prioritization Protocol (MRSPP);
- Chapter 9: Identification and Screening of Remedial Technologies;
- Chapter 10: Development of Remedial Alternatives;
- Chapter 11: Detailed Analysis of Remedial Alternatives; and
- Chapter 12: References.
- Appendix A: Geophysical Data (on compact disc [CD])
- Appendix B: Munitions Debris Disposal/Destruction Documentation
- Appendix C: Laboratory Analytical Tables and Data Validation
- Appendix D: Root Cause Analysis
- Appendix E: Field Work Variances
- Appendix F: Daily Reports
- Appendix G: Risk Management Methodology
- Appendix H: MRSPP Worksheets
- Appendix I: Risk Management Methodology Matrices
- Appendix J: Cost
- Appendix K: Meetings and Key Correspondence
- Appendix L: Photolog
- Appendix M: Grid Maps

2.0 Munitions Response Site Description

2.1 PROJECT LOCATION AND SETTING

The NDNODS Fort Tuthill Small Arms Range North MRS investigation area is located approximately 5 miles south of Flagstaff, Coconino County, Arizona (**Figure 2.1**). The RI investigation area includes the MRS, a possible small arms range safety fan, and a possible artillery range safety fan which comprises a combined 100-acre footprint. The property is owned and operated by Coconino County as Fort Tuthill County Park and is open to the public. The investigation area also includes portions of the Fort Tuthill Luke Air Force Base Recreational Area, which is a DoD cardholder lodge and recreation area. The MRS is characterized by gently rolling terrain with vegetation consisting of dense to sparse stands of Pine-fir conifer forest with grassland (Weston, 2011). A single intermittent stream runs through the center of the MRS; no other surface water bodies are present. MEC, in the form of unexploded ordnance (UXO), may be present in the MRS based on the single UXO recovered during recent (2017) construction activities within the MRS and a practice rocket found by maintenance staff in 2000.

2.2 HISTORICAL USE

2.2.1 A single section of land selected for the location of Fort Tuthill was originally owned by the U.S. Department of Agriculture (USDA) National Forest Service and partially set aside for the University. The section was subsequently exchanged to the Arizona State Land Department and construction of Fort Tuthill began in 1930. An additional three sections of land were obtained for small arms or maneuver training under a Special Use Permit in 1930. An amendment to the Special Use Permit in 1931 removed one section located due east from Fort Tuthill use and designated an additional total of approximately 7,525 acres for artillery training from the USDA National Forest Service. The area was combined with the earlier Fort Tuthill Lease and 1930 Special Use Permit issued for maintaining target ranges and maneuver areas, including the location of the NDNODS Fort Tuthill Small Arms Range.

2.2.2 During the Historical Records Review (HRR) performed during the Site Inspection (SI), the Fort Tuthill Artillery Range was identified as a new MRS, immediately adjacent to, and surrounding the Fort Tuthill Small Arms Range. As a result, the NDNODS Fort Tuthill Munitions Response Area was established comprising the Fort Tuthill Small Arms Range North MRS and the Fort Tuthill Artillery Range MRS.

2.2.3 The NDNODS Fort Tuthill Small Arms Range North MRS was originally identified as a 3.18-acre small arms and adjacent artillery range. The original MRS boundary was recalculated using geographic information system (GIS) data during the HRR and was determined to be 13.39 acres. The former small arms range was used from 1928 through 1955 for training with .30 and .50 caliber water-cooled machine guns and Browning Automatic Rifles (.30 caliber). Firing at the range was conducted from the northeast to the southwest into an impact berm. Exhibits at the Fort Tuthill Museum list weapons used at Fort Tuthill as .30 and .50 caliber machine guns, mortars, bazookas, recoilless rifles, and grenades. However, information regarding the Fort Tuthill Artillery Range MRS indicates that grenades, bazookas, mortars, and artillery were not associated with the small arms range.

2.3 ENVIRONMENTAL SETTING

2.3.1 TOPOGRAPHY AND VEGETATION

The NDNODS Fort Tuthill Small Arms Range North MRS is characterized by gently rolling terrain with elevations ranging from approximately 6,965 feet to 7,010 feet above mean sea level. **Figure 2.2** also portrays the topographic details of the MRS. Vegetation within the MRS consists of dense to sparse stands of Pine-fir conifer forest with grassland (Weston, 2011).

2.3.2 CLIMATE

The average annual low temperature for the Flagstaff, Arizona area is 27°F and the average annual high temperature is 61°F. January is the coldest month of the year with an average low of 11°F and an average high of 43°F. July is typically the warmest month of the year with an average low of 46°F and an average high of 81°F. The average annual rainfall amount in the Flagstaff area is 23.16 inches with August typically being the wettest month with an average rainfall of 3.47 inches. Snow occurs between October and April with the heaviest snowfall in January (18 inches) and an annual average of 77 inches (U.S. Climate Data, 2021).

2.3.3 GEOLOGY AND SOILS

Based on the Final SI Report for NDNODS Fort Tuthill Small Arms Range North MRS the Geology at this MRS consists of predominantly Late Tertiary to Quaternary basalts and cinders underlain by sedimentary Permian-age Kaibab Formation. The Kaibab Formation is described as gray to tan cherty limestone underlying white to tan fine-grained sandstone (Weston, 2012). The Final SI Report for NDNODS Fort Tuthill Small Arms Range North MRS described soils at the site as Gravelly-Sand-Silt/Gravelly-Sand-Clay (Weston, 2012).

2.3.4 HYDROGEOLOGY AND HYDROLOGY

According to the Final SI Report for NDNODS Fort Tuthill Small Arms Range North MRS the groundwater depth at the site is 881 to 1,119 feet below ground surface (bgs) (Weston, 2012). A single intermittent stream runs through the center of the MRS, no other surface water bodies are present. This stream within the MRS is identified by the Wetlands Online Mapper as R4SBC which indicates riverine, intermittent, streambed, seasonally flooded. **Figure 2.3** shows the stream feature at the NDNODS Fort Tuthill Small Arms Range North MRS. During the time of the fieldwork (September 28, 2020 through November 16, 2020), no surface water was observed present in this feature or elsewhere within the MRS footprint.

2.3.5 ENDANGERED SPECIES, SENSITIVE HABITATS, AND HISTORICAL OR CULTURAL RESOURCES

2.3.5.1 Fourteen federally-listed endangered species and eleven federally-listed threatened species are known to or are believed to be present in Coconino County (USFWS, 2021). According to the U.S. Fish and Wildlife Service (USFWS) range information maps, one federally-listed endangered and three federally-listed threatened species are known to occur within the area of the MRS. Federally-listed threatened and endangered species that may be a concern within the MRSs include the California condor (avian), Mexican Spotted Owl (avian), Yellow-billed cuckoo (avian), and the Northern Mexican Gartersnake (reptile).

2.3.5.2 The Arizona Game and Fish Department (AZGFD) On-line Environmental Review Tool does not list any critical habitat or Important Bird Areas within the MRS (AZGFD, 2021). The MRS is within a special area for the Mexican Wolf (Canis lupus baileyi), as the area of the MRS is part of the "Mexican Wolf Experimental Population Area". **Table 2.1** provides species information including photographs and habitat information. Upon initial mobilization for the conduct of the RI fieldwork and periodically as part of the morning safety briefings, project field personnel reviewed photographs and habitats of both common and endangered plant and animal species indigenous to the area. No endangered plant or animal species were observed during the entirety of the field effort between September 28, 2020 through November 16, 2020.

2.3.5.3 Cultural resources include the buildings and structures of the former Fort Tuthill (30 total structures) that are part of the Fort Tuthill Historic District and listed on the National Register of Historic Places (NRHP) (NPS, 2021). No other known cultural resources or sites were identified during historical research in advance of the conduct of fieldwork. Similarly, no evidence of potential cultural resources was encountered during field reconnaissance or intrusive investigations associated with this RI.

Table 2.1 Endangered Species

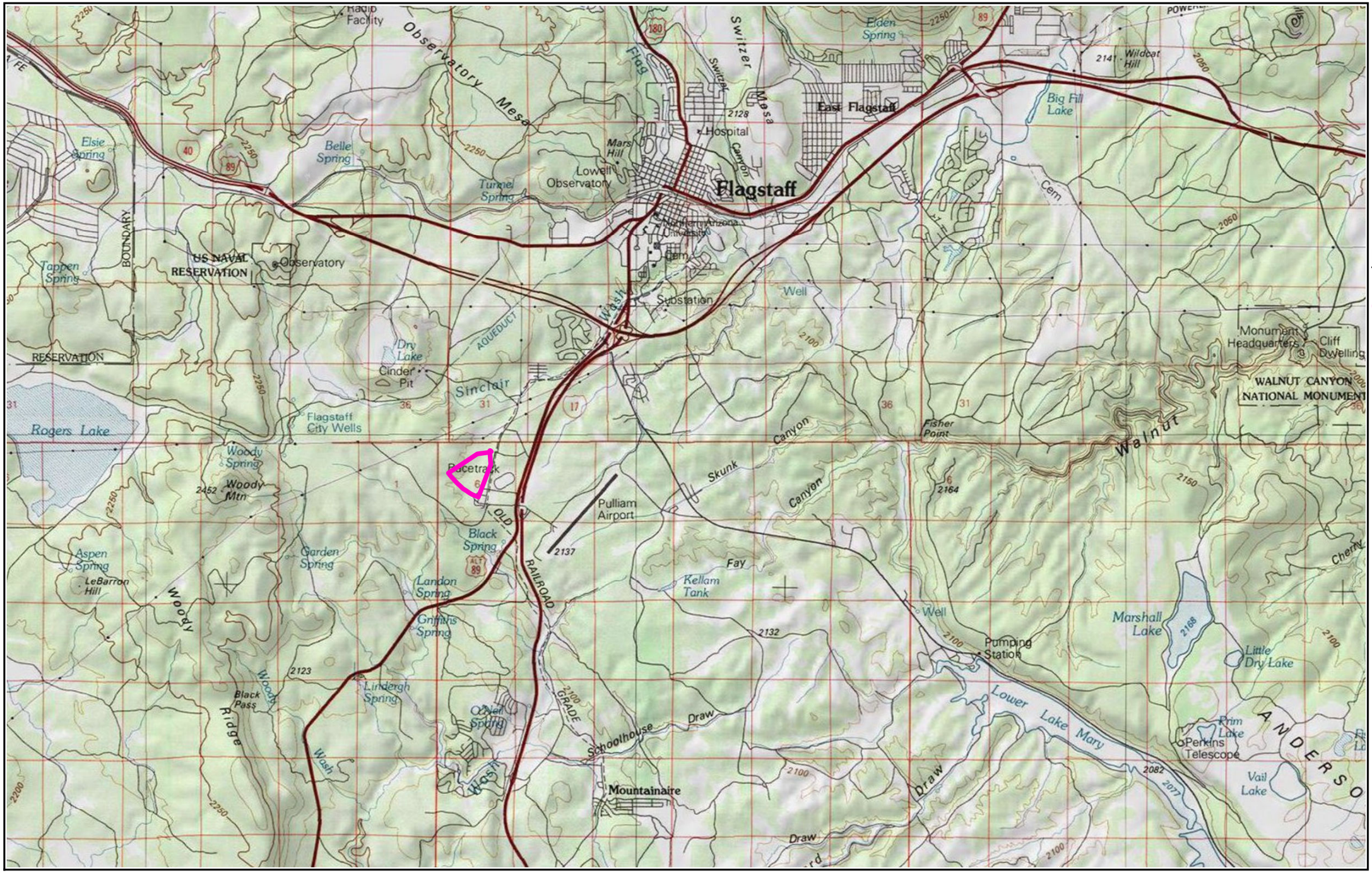
Species		Federal Status	General Information
California Condor		Endangered	117-134 cm. Huge and unmistakable. Black with white wing-linings and silvery panel on upper secondaries. Head naked and orange/red. Immatures with black head and underwing mottled dark. Soars on horizontal wings with primaries curled up.
Mexican Spotted Owl		Threatened	Unlike most owls, Mexican spotted owls have dark eyes. They are an ashy-chestnut brown color with white and brown spots on their abdomen, back and head. Their brown tails are marked with thin white bands. They lack ear tufts. Young owls less than 5 months old have a downy appearance. Females are larger than males.

Species		Federal Status	General Information
Yellow-Billed Cuckoo		Threatened	Yellow-billed Cuckoos are fairly large, long, and slim birds. The mostly yellow bill is almost as long as the head, thick and slightly downcurved. They have a flat head, thin body, and very long tail. Wings appear pointed and swept back in flight. Yellow-billed Cuckoos are warm brown above and clean whitish below. Their blackish face mask is accompanied by a yellow eye-ring. In flight, the outer part of the wings flash rufous. From below, the tail has wide white bands and narrower black ones.
Northern Gartersnake		Threatened	With a maximum known length of 44 inches (in) (112 centimeters (cm)), it ranges in background color from olive to olive-brown to olive-gray with three stripes that run the length of the body. The middle dorsal stripe is yellow and darkens toward the tail. The pale yellow to light-tan lateral stripes distinguish the Mexican gartersnake from other sympatric (co-occurring) gartersnake species because a portion of the lateral stripe is found on the fourth scale row, while it is confined to lower scale rows for other species.
Mexican Wolf		Endangered At project site listed as Experimental Population Non-Essential	The Mexican wolf is the smallest extant gray wolf subspecies in North America. Adults weigh 50 to 90 pounds (lb) with a length of 5 to 6 ft and height at shoulder of 25 to 32 in (Brown, 1988). Mexican wolves are typically a patchy black, brown to cinnamon, and cream color, with primarily light underparts (Brown, 1988). Solid black or white coloration, as seen in other North American gray wolves, does not exist in Mexican wolves. The basic life history for the Mexican wolf is similar to that of other gray wolves.

Source: USFWS, 2020

Figure 2.1
NDNODS Fort Tuthill Small Arms Range North
Site Location
Coconino County, Arizona

PARSONS



Legend

Fort Tuthill Small Arms Range North MRS Boundary

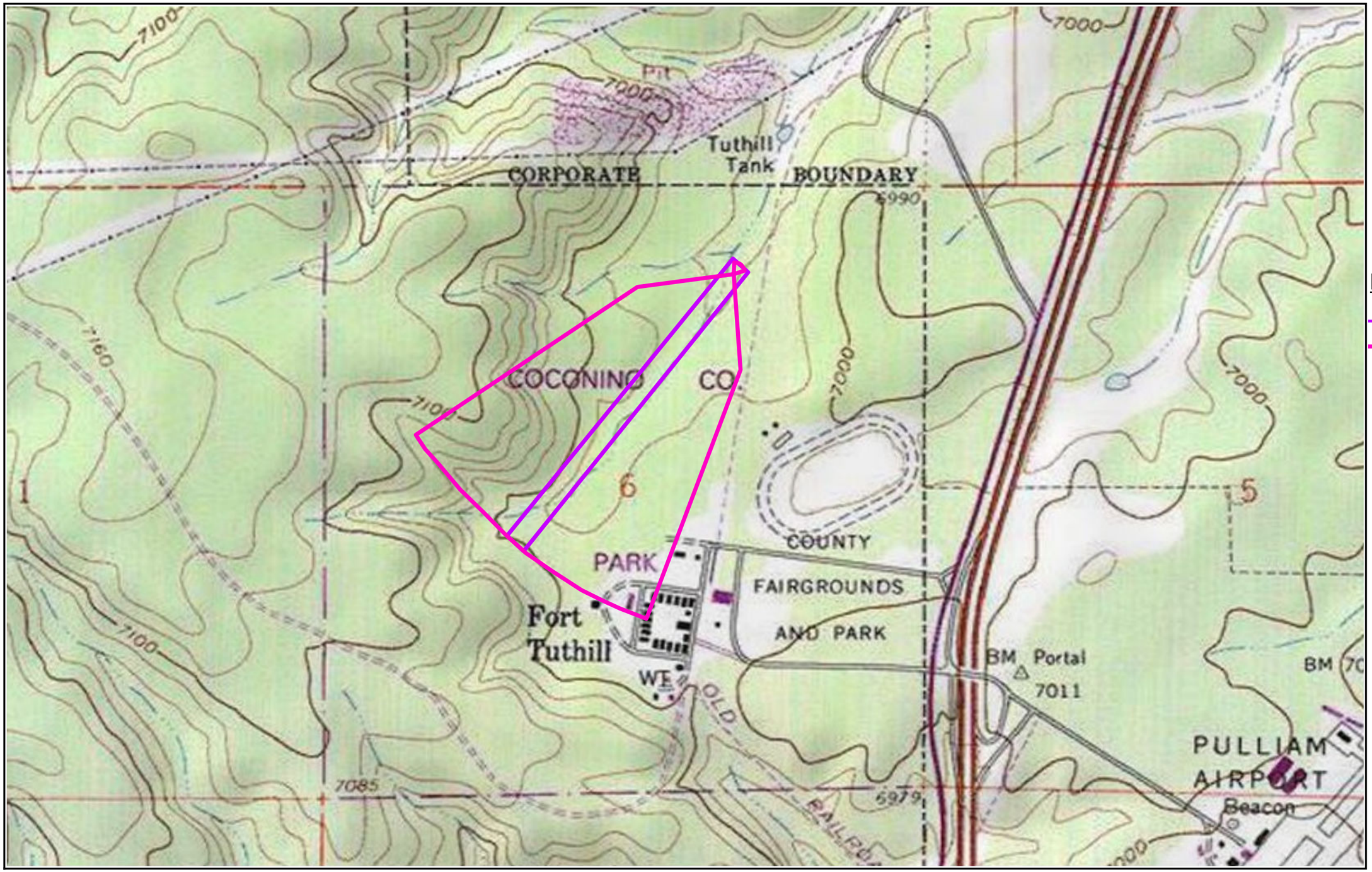
1,000 500 0 1,000
Meters

N

PROJECT NUMBER:
100087.0538.110208.03002
June 2021

Figure 2.2
NDNODS Fort Tuthill Small Arms Range North
Site Layout
Coconino County, Arizona

PARSONS



Site Location in Arizona

Legend

- Small Arms Range North
- Original Range Safety Fan

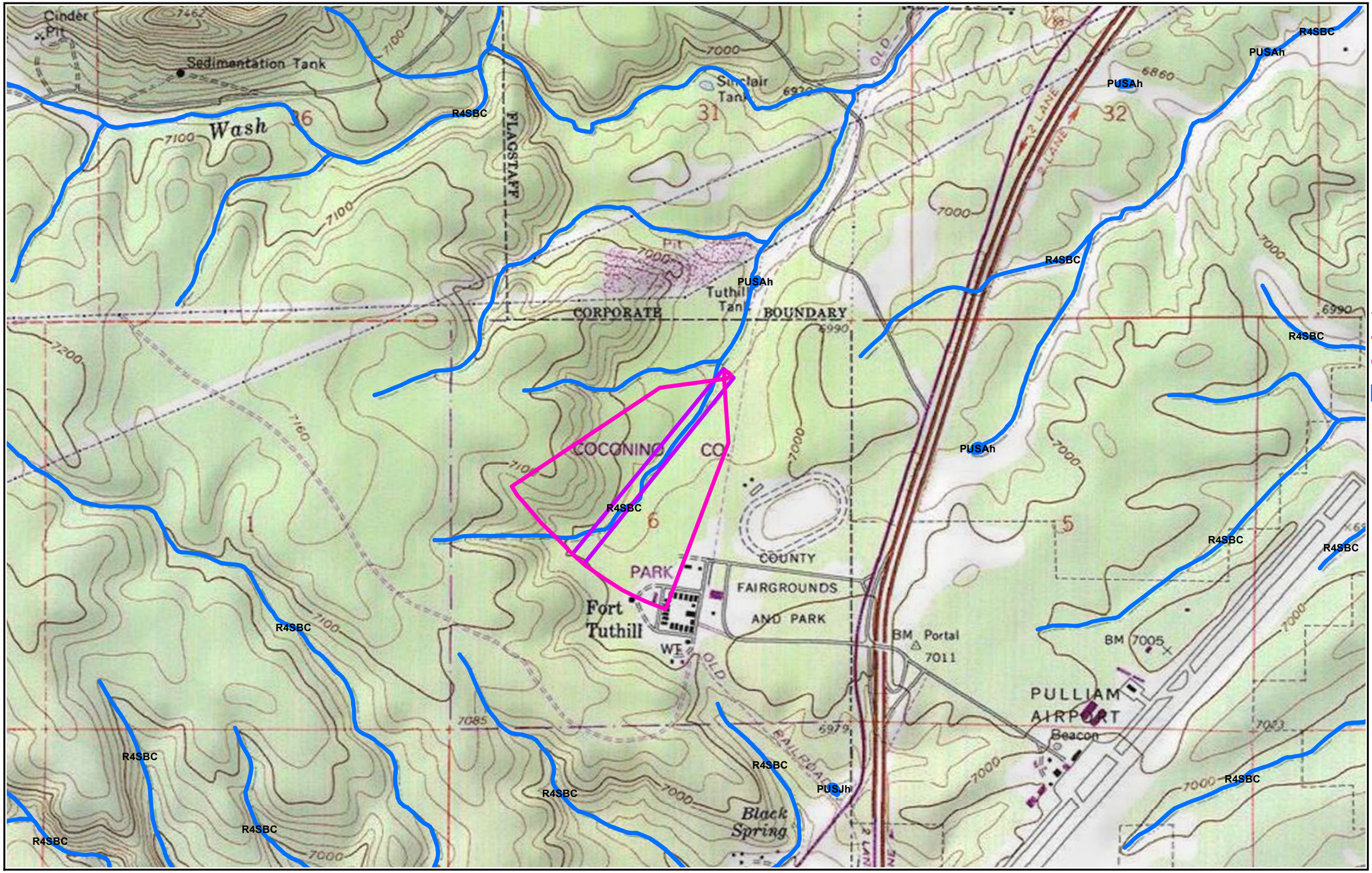
150 75 0 150
Meters

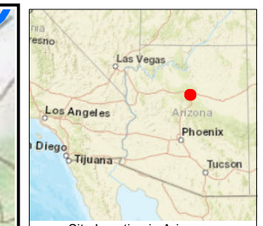
N

PROJECT NUMBER:
977203.0009.02019.90002
June 2021

Figure 2.3
NDNODS Fort Tuthill Small Arms Range North
Wetlands
Coconino County, Arizona

PARSONS





Site Location in Arizona

Legend

- Small Arms Range North
- Original Range Safety Fan
- Wetland (U.S. Fish and Wildlife Service)

R4SBC: Riverine, Intermittent, Streambed, Seasonally Flooded.
PUSAh: Palustrine, Unconsolidated Shore, Temporary Flooded, Diked/Impounded.

200 100 0 200
Meters

N

PROJECT NUMBER:
977203.0009.02019.90002
June 2021

2.4 PREVIOUS INVESTIGATIONS/INCIDENTS

Five relevant investigations/incidents have occurred at the NDNODS Fort Tuthill Small Arms Range North MRS. These include:

- 2008 Preliminary Assessment (PA) Report, Final State/Territory Inventory Report, National Guard Bureau, Non-Department of Defense Owned Non-Operational Defense Sites Inventory, Arizona (EA, 2008)
- 2011 Historical Records Review (HRR), Army National Guard Munitions Response Sites, Site Inspection Phase, Arizona (Weston, 2011)
- 2012 Site Inspection (SI) Report, Army National Guard Munitions Response Sites, Site Inspection Phase, Arizona (Weston, 2012)
- October 2017 MEC Discovery (2.36-inch bazooka rocket), Incident/Investigation Report, Case S17-04467 (Coconino, 2017)
- 2020 Remedial Investigation (RI) Project Planning, Systematic Planning Process (SPP) Memorandum & Associated Documentation (Parsons, 2020)

2.4.1 2008 PRELIMINARY ASSESSMENT

The PA Report indicated the former range was utilized as a small arms range from 1928 through 1955. The MRS boundary was determined from historical records which included a sketch map of the former target range. An area listed as an Estimated Rifle Range was included to depict the inferred location based on the sketch map. The direction of fire was from north to south into the impact berm at the base of a hill 50 to 100 feet high. The site visit conducted in support of the PA observed no evidence of MEC or munitions debris (MD); however, interviews conducted with the Fort Tuthill Museum curator and with personnel from the Fort Tuthill County Park indicated that MD from a possible expended bazooka round had been observed on the site. The NDNODS boundary presented in the PA Report is a combination of an exclusion area and original Lease for training at Fort Tuthill (EA, 2008).

2.4.2 2011 HISTORICAL RECORDS REVIEW

The HRR included additional research for the NDNODS Fort Tuthill Artillery Range MRS at the Northern Arizona University Cline Library, the Flagstaff Public Library, and the Fort Tuthill Museum. Findings from the Weston 2011 HRR are presented below:

- The Arizona Legislature appropriated funds for the construction of an encampment at Fort Tuthill in 1919. A single section of land selected for Fort Tuthill was originally owned by the USDA National Forest Service and partially set aside for the University. The section was subsequently exchanged to the Arizona State Land Department for the USDA National Forest Service. After the exchange, construction at Fort Tuthill began in 1930 after a lease was obtained by the Arizona ARNG from the Arizona State Land Department.
- A Special Use Permit dated August 29, 1930 was issued for three additional Sections to the original lease for use in small arms or maneuver training.
- An amendment to the Special Use Permit was issued in August 1931 removing one section located due east from Fort Tuthill.
- Exhibits at the Fort Tuthill Museum list weapons used at Fort Tuthill as .30 and .50 caliber machine guns, mortars, bazookas, recoilless rifles, and grenades. However, training for use of grenades, bazookas, mortars, and artillery was not associated with the small arms range, based on information regarding the NDNODS Fort Tuthill Artillery Range MRS. Observations of bazooka rocket MD reported in the PA were inferred to be the result of artillery or maneuver training activities in the surrounding areas, not

within the small arms MRS boundary. Therefore, the type of munitions associated specifically for the small arms MRS is limited to .30 and .50-caliber machine guns.

- Although the majority of small arms training is inferred to have occurred within the defined MRS, a map on display at the Fort Tuthill Museum indicates that a separate area was used for machine gun training. A relatively open area is visible on a 1954 aerial photograph that coincides with the historical map, but it was in the portion of Fort Tuthill generally designated for maneuvers or artillery training. Photographs from the 1990s onward indicate that a portion of the area has been developed for mining/supply of aggregate or cinders on private land.
- The boundary of the Small Arms Range MRS is generally consistent with present and historical physical features at the site and has not been expanded or modified.
- The current estimated size of the MRS is 13.39 acres, compared to the 3.2 acres in the PA Report. The revision is a result of more accurate recalculations based on GIS data from the ARNG Directorate.

2.4.3 2012 SITE INSPECTION

The findings of the 2012 SI Report are presented below:

- Right-of-entry (ROE) for the Site Inspection was limited to 2.6 acres associated with the target impact berm in the southern portion of the MRS.
- The field investigation confirmed that the range configuration and features were consistent with the HRR results. Evidence of military activities included a target impact berm at the southern end of the MRS and a second impact berm or firing line at the northeastern end of the area surveyed.
- The southern target berm was “L” shaped with the longer portion approximately 10 feet high, 150 feet long, and 20 feet wide. A shorter extension of the berm was approximately 50 feet in length oriented from the southeastern end of the primary target berm to the northeast.
- A second target impact berm was observed at the northeastern end of the area inspected (200 yards from the southern target impact berm) and consisted of a brick and concrete retaining wall approximately 5 feet in height.
- No targets or remnants of targets were observed in the vicinity of the MRS. A single civilian .38-caliber round was identified approximately 10 feet in front of the southern target impact berm. No other small arms ammunition debris, MEC, or MD were identified in the portion of the MRS inspected.
- Soil samples collected for lead during the SI did not exceed the Arizona SI screening level of 400mg/kg.
- The SI recommended that the NDNODS Fort Tuthill Small Arms Range MRS be separated into two MRSs consisting of the NDNODS Fort Tuthill Small Arms Impact Area MRS (2.6 acres) and the NDNODS Fort Tuthill Small Arms Range North MRS (10.79 acres). For this RI, the NDNODS Fort Tuthill Small Arms Range North MRS footprint was designated as 100 acres and included both these subareas as well as an expanded area comprising a 2.36-inch bazooka rocket range fan overlain on the small arms range.
- As a result of the SI, the NDNODS Fort Tuthill Small Arms Impact Area MRS was recommended for No Further Action (NFA) for MEC and MC. The NDNODS Fort Tuthill Small Arms Range North MRS, where ROE was not granted, was recommended for SI with 5-year reviews until access is granted for the SI. ROE was granted for the entire expanded NDNODS Fort Tuthill Small Arms Range North MRS footprint (100-acres) assessed during this RI with the exception of a small sliver (< 1 acre) located in the southeastern extreme of the MRS. The Project Team determined this area inconsequential to the successful conduct of the RI due to its small size and location along the MRS perimeter.

2.4.4 OCTOBER 2017 MEC DISCOVERY

On October 31, 2017 the Coconino County Sheriff's Office was contacted to report the presence of what was determined to be a World War II bazooka munition (2.36-inch rocket) found in a construction area west of the Flagstaff Extreme Adventure Course. The Flagstaff Police Department Bomb Squad responded to the scene and determined that it was possibly a live round. The Luke Air Force Base Explosive Ordnance Disposal (EOD) responded to the scene on November 1, 2017 and identified the item as a World War II shoulder mounted anti-tank rocket. X-Ray imagery of the item indicated that it was HE; therefore, the munition was destroyed by controlled detonation.

2.4.5 2020 RI PROJECT PLANNING

Following the initial SPP meeting on January 30, 2020 and discussion of the upcoming RI, the landowner (CCPR) informed the Project Team that additional information had been discovered when discussing the MRS with the maintenance staff. The Project Team was informed that a previously unreported blue, practice 2.36-inch bazooka rocket had been found within the MRS by maintenance personnel in 2000. The item was found on the hillside behind the termination berm at the small arms range and the approximate location was added to the project figures. As a result of this discovery, the CSM was re-evaluated by the Project Team during a post-SPP #1 meeting held on March 3, 2020 and an alternate potential firing point and range configuration was identified based on topographic conditions and locations presented for the two rocket findings. This alternate range fan mostly overlaps the prior defined 100-acre MRS with small additional portions outside the current MRS (Figure 2.5). These additional areas were considered with regard to the RI but have yet to be formally included in the MRS footprint.

2.5 CURRENT AND FUTURE LAND USE

The NDNODS Fort Tuthill Small Arms Range North MRS is owned and operated by Coconino County (CCPR) as Fort Tuthill County Park and is open to the public. Land use is recreational with hiking, biking, camping, archery, equestrian, and snow sporting. Park areas within the MRS include the multiple use trails, Flagstaff Extreme Adventure Course (obstacles and zipline course), Fort Tuthill Campground, Bike Park, Equestrian Cross-County Jump Course, and Flagstaff Snow Park (snow tubing park). The investigation area also includes portions of the Fort Tuthill Luke Air Force Base Recreational Area, which is a DoD cardholder lodge and recreation area. The Fort Tuthill County Park also hosts the county fair annually along with other events at their fairgrounds located adjacent to the MRS. No change from recreational land use is expected in the future, though construction activities may take place that are related to the recreational use.

2.6 CONCEPTUAL SITE MODEL

2.6.0.1 The conceptual site model (CSM) is a description of a site and its environment that depicts the MEC and MC migration/exposure pathways, and the possible human and ecological receptors for those pathways based on site-specific conditions and land use. It is necessary to develop the CSM to evaluate risks posed to potential receptors under current and future land use scenarios. A CSM is dynamic and represents the current understanding of the MRS. For this reason, the CSM is evaluated and revised each time new information is received.

2.6.0.2 For the purposes of this RI/FS, a preliminary CSM was developed for the NDNODS Fort Tuthill Small Arms Range North MRS in accordance with Engineer Manual (EM) 200-1-12. This preliminary CSM, presented in Table 10.1 of the approved Final UFP-QAPP (Parsons, 2020), was based on what was known about the MRS *prior* to conducting the RI. This table described the known or suspected contamination sources, potential/suspected location and distribution of contamination, contamination source or exposure medium, current, and future receptors, and potentially complete exposure pathways. The CSM development process included reviewing historical data to identify data gaps, investigation areas, potential receptors, current land use, and potentially complete exposure pathways for MEC and MC (if present). This CSM was used to focus the development of the general Technical Approach for the RI. A visual CSM diagram and map were also developed to convey this information and facilitate communication with stakeholders in an easy-to-understand format (Figures 10.4 and 10.5 of the approved Final UFP-QAPP [Parsons, 2020]).

2.6.0.3 The preliminary CSM indicated that MEC, in the form of UXO, *may* be present in the MRS based on the single reported UXO recovered during recent construction activities (2017) within the MRS and the practice rocket found by maintenance staff in 2000. It was anticipated that MEC would most likely be found in identified "high-use areas" (HUAs) within the MRS. Areas outside the HUAs that have the potential for low levels of MEC contamination would be designated as "low-use areas" (LUAs). Areas that are not suspected of MEC contamination based on the CSM and RI results would be considered "no evidence of use" (NEUs) areas.

2.6.0.4 The CSM presented in this subchapter represents the current understanding of the MRS subsequent to the conduct of the RI. The CSM summarizes which potential receptor exposure pathways for MEC and MC are (or may be) complete and which are (and are likely to remain) incomplete. An exposure pathway is considered incomplete unless all four of the following elements are present (USEPA, 1989):

- A source of contamination
    - An MRS has confirmed MEC or significant MD indicative of potential residual presence of MEC
    - An MRS, based on MEC or significant MD presence, has potential for MC to have leached and contaminated soil or other media.
- An environmental transport and/or exposure medium (MC in soil is shallow and transported via fugitive dust).
- A point of exposure at which the contaminant can interact with a receptor (areas of contaminated surface soil are present in where recreational activities or construction could occur).
- A receptor and a likely route of exposure at the exposure point (an on-site resident or recreational user disturbs the contaminated surface soil).

2.6.0.5 If all four factors are present, the exposure pathway is complete. If any single factor is not present, the specific pathway would be incomplete. An incomplete exposure pathway indicates there are no current means by which a receptor (human or ecological) can be exposed to either MEC or MC and, therefore, no risks from exposure to MEC or MC would be expected associated with that pathway.

2.6.0.6 Based on the results of the MEC and MC characterizations conducted and as presented in **Subchapters 5.1** and **5.2**, the preliminary CSM, described in the approved Final UFP-QAPP (Parsons, 2020), was reviewed and updated to reflect any new applicable information. The preliminary CSM for Fort Tuthill Small Arms Range North MRS indicated potentially complete MEC and MC exposure pathways were present for receptors at the MRS. This subchapter describes the revised CSM as modified based on the results of this RI. Potential MEC exposure pathways remain potentially viable; however, human health and ecological MC exposure pathways are no longer considered complete due to absence of MC contamination. The results of the RI and revised CSM are summarized in **Table 2.2 and Figures 2.4, 2.5, 2.6, and 2.7**.

2.6.1 HUMAN AND ECOLOGICAL RECEPTORS

The NDNODS Fort Tuthill Small Arms Range North MRS is owned and operated by Coconino County (CCPR) as Fort Tuthill County Park and is open to the public. Land use is recreational with hiking, biking, camping, archery, equestrian, and snow sporting. Potential current and future receptors include on-site workers (i.e., Fort Tuthill County Park Workers), including construction workers, and site visitors/recreational users (hikers, bikers, horseback riders, campers, archers). Park areas within the MRS include the multiple use trails, Flagstaff Extreme Adventure Course (obstacles and zipline course), Fort Tuthill Campground, Bike Park, Equestrian Cross-County Jump Course, and Flagstaff Snow Park (snow tubing park). No change from recreational land use is expected in the future, though construction activities may take place that are related to the recreational use. These activities involve potential intrusive activity that may exceed 60 cm (24 inches) bgs by on-site workers, construction workers, and site visitors/recreational users. Potentially affected ecological receptors include plants, soil invertebrates, reptiles, birds, mammals, and amphibians. Ecological species are not considered receptors for MEC.

2.6.2 MEC EXPOSURE PATHWAYS

2.6.2.1 The preliminary CSM for the NDNODS Fort Tuthill Small Arms Range North MRS indicated potentially complete MEC exposure pathways were present for receptors at the MRS, including on-site workers (i.e., Fort Tuthill County Park Workers), construction workers, and site visitors/recreational users (hikers, bikers, horseback riders, campers, archers). Three critical elements are required for a complete MEC exposure pathway: a source of MEC, a receptor, and the potential for interaction between the source and the receptor.

2.6.2.2 Munitions in the form of potential UXO have not been found during previous investigations; however, one potential UXO item was reportedly recovered during recent (2017) construction activities conducted within the MRS and a single practice rocket was found by maintenance staff in 2000. **Table 2.2** presents the munitions known or suspected to have been used within the MRS.

2.6.2.3 Potential HUAs and LUAs at the NDNODS Fort Tuthill Small Arms Range North MRS were characterized using a two-step process. First, geophysical data was used to designate high anomaly density (HD) and low anomaly density (LD) areas. Second, intrusive investigation within the HD areas was used to confirm the presence of MEC or large amounts of MD to determine if an HD area should be designated as an HUA. Confirmed HUAs would be considered MEC-contaminated. During the RI, no HUAs were identified (see Subsection 3.5). LD areas were designated as either an LUA or NEU area based on a combination of lines of evidence from the site history, location relative to potential HUAs, intrusive results, and/or previous investigations. Areas within the MRS demonstrated to have high or low surface or subsurface anomaly density, but no signs of munitions use and no evidence of past use, would be considered NEU areas. MEC is not suspected to be present in an NEU area. No signs or evidence of munitions use would include a lack of MEC and MD (including small arms), as well as no targets or range features that would indicate use as a range. For the NDNODS Fort Tuthill Small Arms Range North MRS the entire 100-acre MRS footprint was designated as an LUA. No HUA or NEU areas were identified (see Subsection 3.5).

2.6.3 MC EXPOSURE PATHWAYS

2.6.3.1 With regard to MC, the preliminary CSM indicated that explosives and MC metals (antimony, copper, lead, and zinc) may have been released to surface and subsurface soil within HUAs (if present). The MC sampling conducted during the SI was limited to the analysis of lead in soil which was not detected in any of the samples collected above the screening level (400 mg/kg). MC sampling during the RI was contingent on the identification of one or more HUAs and would include sampling for explosives and the MC metals identified above. However, based on the RI data, the entire MRS was designated as an LUA and thus the criteria for implementation of MC sampling was not met. Following Project Team discussions to include Arizona DEQ, MC samples were ultimately collected and analyzed for explosives only in four SUs coincident with the four grid locations where MD was recovered. No explosive analytes were detected in any of the samples. Further, groundwater contamination is not anticipated due to the depth to groundwater in the area and the absence of soil contamination and was therefore not sampled. In addition, no perennial surface water bodies, or surface water pathways are present within the MRS; therefore, surface water and sediment samples were not collected. Additionally, no water was observed during the RI field activities in intermittent surface water conveyances.

2.6.3.2 An exposure assessment for MC includes identification of potential exposure pathways, receptors, and exposure scenarios along with quantification of exposure to MC. For MC exposure pathways to be complete, all the following must be present:

- A source for contamination,
- An environmental transport and/or exposure medium,
- A point of exposure where contaminants contact a receptor, and
- A likely route of exposure at the point of exposure.

2.6.3.3 Based on the results of the RI described in **Subchapter 5.2**, no COPCs or COPECs have been identified within the NDNODS Fort Tuthill Small Arms Range North MRS. Consequently, there is no complete exposure

pathway for human health or ecological receptors from potential exposure to at the MRS. Therefore, there are no MC risks.

2.7 PRELIMINARY REMEDIATION GOALS

2.7.1 Preliminary remediation goals are site-specific and contaminant-specific and define the conditions considered by stakeholders to be protective of human health and the environment. As with the CSM, preliminary remediation goals are reevaluated and refined throughout the RI/FS process as new information becomes available.

2.7.2 The preliminary remediation goal for MEC at the NDNODS Fort Tuthill Small Arms Range North MRS is to prevent any interaction between residual MEC and human receptors accessing the MRS. The preliminary remediation goals for MEC could be achieved by measures such as removing potential MEC present to a depth at which they no longer present a hazard to the anticipated human receptors, or by implementing land use controls (LUCs) that minimize the possibility of receptors being exposed to MEC. For the NDNODS Fort Tuthill Small Arms Range North MRS, the RI did not confirm any additional MEC presence, identified minimal MD contamination, and no discernible HUA was present (Subsection 3.5).

2.7.3 The preliminary remediation goal for MC was initially based on the screening values that were agreed to by the Project Team as being protective of the identified exposure pathways at the NDNODS Fort Tuthill Small Arms Range North MRS. The preliminary remediation goal is to ensure that any identified MC contamination at the MRS determined to pose an unacceptable risk to human health or the environment is addressed to minimize or mitigate those risks. The preliminary remediation goal for MC could be achieved by measures such as removing contaminated media to a depth at which they no longer present risks to the anticipated human receptors, or by implementing LUCs that minimize the possibility of receptors being exposed to MC. Given the absence of lead contamination detected during the SI, lack of identification of a significant MEC/MD source during the RI, absence of an HUA, and lack of detectable explosives contamination from locations where MD was recovered; soil removal action options are not warranted.

Table 2.2 Conceptual Site Model Summary, NDNODS Fort Tuthill Small Arms Range North MRS

Site Details	Details and Results of Remedial Investigation						Revised Conceptual Site Model Summary				
	Known or Suspected Contamination Source(s)	Potential/Suspected Location and Distribution	Investigation Method	Investigation Location(s)	RI Investigation Acreage / Number of Samples	Investigation Results	Confirmed or Suspected Contamination Source(s)	Confirmed Location and Distribution	Source or Exposure Medium	Current and Future Receptors	Complete Exposure Pathway
NAME: NDNODS Fort Tuthill Small Arms Range North MRS **Acreage**: Expanded to 100 acres encompassing the former MRS and also including acreage based on application of 2.36-inch bazooka rocket range fan. **Suspected Past DoD Activities (*release mechanisms*)**: Small arms training; however, new information provided since the SI in 2012 suggests 2.36-inch bazooka rockets may have been used at this range. No MEC and only sparse MD to include pieces of 57mm HE recoilless rifle munitions and 60mm HE mortars were identified within the LUA during the RI. Criteria were not met within the MRS to designate an HUA. **Current and Future Land Use**: The MRS is currently used for recreational purposes including hiking, biking, horseback riding, archery, and camping. Future use is not expected to change.	Suspected MEC and MD from the following munitions types have been recovered on site either historically or as part of this RI: • *Rocket, 2.36 inch, HEAT, M6 Series* • *Rocket, 2.36 inch, Practice, M7** • *Recoilless Rifle, 57mm, HEAT* • *Mortar, 60mm, HEAT,* M69 **Note that the M7 only has energetic material present if the rocket motor is unfired.*	HD Areas: areas of high anomaly density delineated using Visual Sample Plan (VSP). Based on the intrusive investigation results from the RI, the HD area were evaluated for potential to be: • A HUA potentially containing HE UXO • A HUA containing only practice munitions, or • Not a HUA (part of LD/LUA area) Although several small HD areas were identified, the RI confirmed no HUAs were present within the MRS (see Subsection 3.5).	Geophysical surveys using conventional DGM followed by intrusive investigation of anomalies	Transects throughout the MRS and grids in the HD areas (potential HUAs) of the MRS (**Figure 3.1**)	1.61 acres of HD grids (7) with 736 anomalies intrusively investigated	Total of 5 MD items recovered (Grids 1 and 7)	MEC and MD types as listed in *Known or Suspected Contamination Source(s)* column of this table	No MEC was recovered or confirmed within the MRS footprint during the RI fieldwork. As a result, no HUAs were identified. Due to the absence of MEC and the sparse amount of MD identified during the RI within the HD areas, the entire site was designated as an LUA. The portion of the MRS of the LD area where evidence of munitions use exists (i.e., is contained in the CSM or found during the field investigation) was designated as an LUA.	Surface or subsurface soil	Potential current and future receptors include on-site workers (i.e., Fort Tuthill County Park Workers), including construction workers, and site visitors/recreational users (hikers, bikers, horseback riders, campers, archers). Future land use is anticipated to be similar to current use.	**YES** However, no MEC was recovered during the RI and only sparse MD was present (no HUA). Exposure to potential surface and/or subsurface MEC (direct contact on surface, possible intrusive activities to 60 cm (24 inches) bgs or more by on-site, construction workers, site visitors/recreational users) is possible.
		LD/LUA Areas: areas of low anomaly density delineated using VSP. The project team delineated the LD area and limited evidence of munitions use was confirmed resulting in the LD area being determined to represent an LUA. For the NDNODS Fort Tuthill Small Arms Range North, the entire MRS was ultimately designated as an LUA based on absence of MEC and sparse MD identified during the RI.	Geophysical surveys using DGM and intrusive investigation	Transects throughout the MRS and grids in the LD areas of the MRS (**Figure 3.1**)	1.15 acres of LD grids (5) with 264 anomalies intrusively investigated	Total of 3 MD items recovered (Grids 2 and 5)					

Site Details	Details and Results of Remedial Investigation						Revised Conceptual Site Model Summary				
	Known or Suspected Contamination Source(s)	Potential/Suspected Location and Distribution	Investigation Method	Investigation Location(s)	RI Investigation Acreage / Number of Samples	Investigation Results	Confirmed or Suspected Contamination Source(s)	Confirmed Location and Distribution	Source or Exposure Medium	Current and Future Receptors	Complete Exposure Pathway
	MC samples collected during the SI focused on lead contamination related to small arms training. Lead was not detected at concentrations exceeding the screening level and the MRS was recommended for NFA for MC. Since suspect MEC was identified within the MRS since the completion of the SI, MC sampling was planned if HUAs were identified in order to assess potential MC contamination where MEC or significant MD was found. However, the entire MRS was ultimately designated as an LUA based on absence of MEC and sparse MD identified during the RI. Criteria were not met within the MRS to designate an HUA. Potential MC: Explosives; antimony, copper lead, and zinc.	Potentially present in surface and subsurface soil in high use areas (HUA) only; not expected in LUAs or NEUs. Based on the RI data, the entire MRS was designated as an LUA and MC sampling was not warranted. However, following Project Team discussions to include Arizona DEQ, MC samples were collected and analyzed for explosives in SUs coincident with the four grid locations where MD was recovered. No detectable explosives concentrations were identified.	Collection of surface soil samples using ISM. Due to the lack of MEC and sparse amount of MD identified during the RI, no HUA was identified and thus the criteria for MC sampling were not met. However, following Project Team discussions to include Arizona DEQ, MC samples were collected and analyzed for explosives in SUs coincident with the four grid locations where MD was recovered. No detectable explosives concentrations were identified.	Grid locations where MD was recovered during the intrusive investigation (**Figure 3.2**).	Four surface soil samples collected using ISM and analyzed for explosives.	No explosives detected in any of the four surface soil ISM samples.	*COPCs:* NA *COPECs:* NA	NA	NA	Potential current and future human receptors include on-site workers (i.e., Fort Tuthill County Park Workers), including construction workers, and site visitors/recreational users (hikers, bikers, horseback riders, campers, archers). Current and future ecological receptors.	**Human Health: NO** **Ecological: NO**

Future land use is anticipated to be similar to current use.

Figure 2.4 Conceptual Site Model Diagram

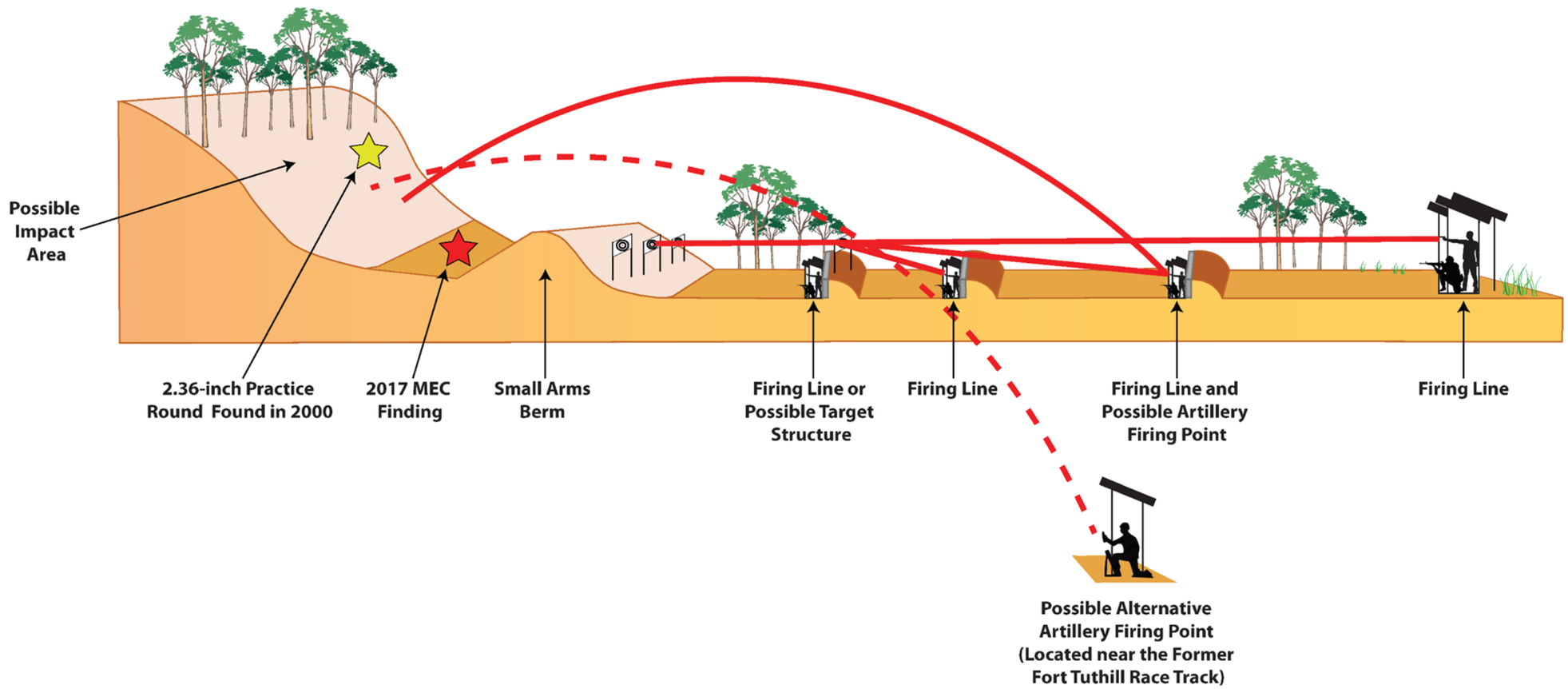
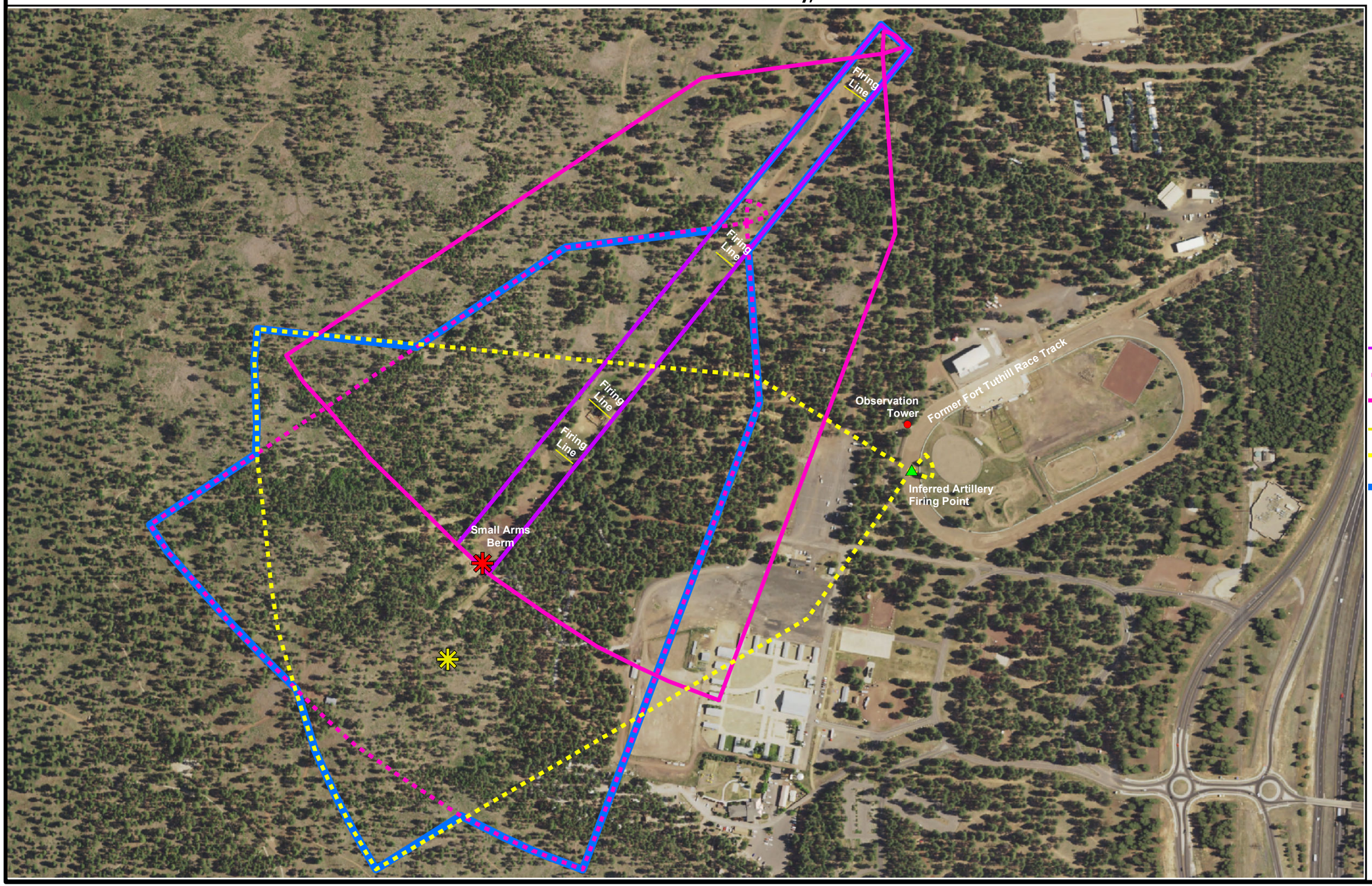
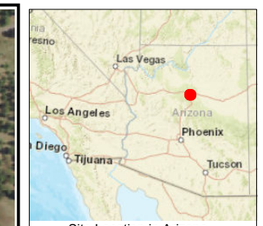


Figure 2.5
Preliminary Conceptual Site Model
NDNODS Fort Tuthill Small Arms Range North
Site ID: AZHQ-005-R-01
Coconino County, Arizona

PARSONS





Site Location in Arizona

Legend

- 2.36-inch Practice Round Found in 2000
- 2017 MEC finding
- Small Arms Range North
- Possible Range Safety Fan
- Original Range Safety Fan
- Firing Line
- Possible Artillery Range Safety Fan
- Investigation Area

80 40 0 80
Meters

N

PROJECT NUMBER:
977203.0009.02019.90002
June 2021

Figure 2.6 Conceptual Site Model – Exposure Pathways Diagram

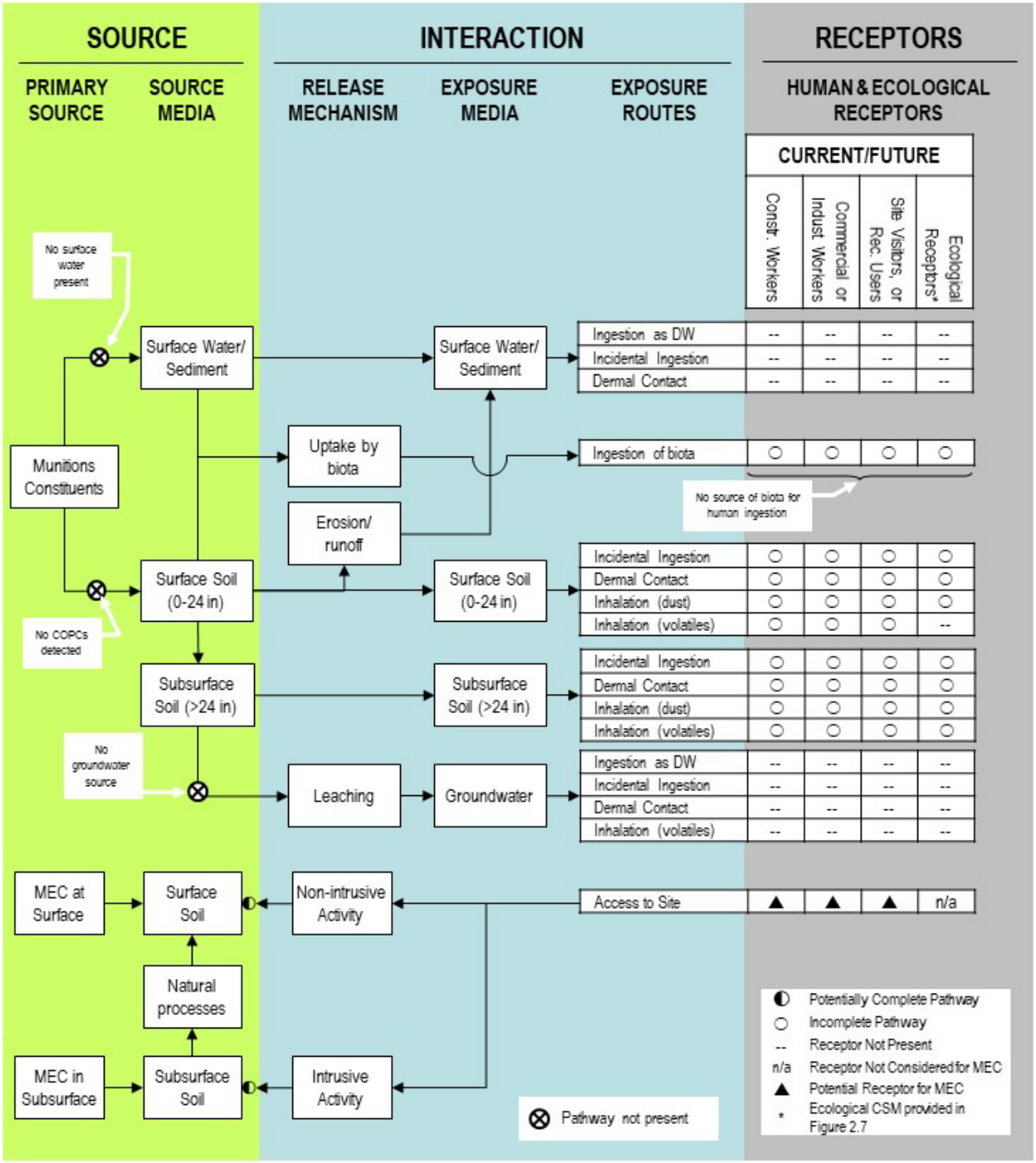
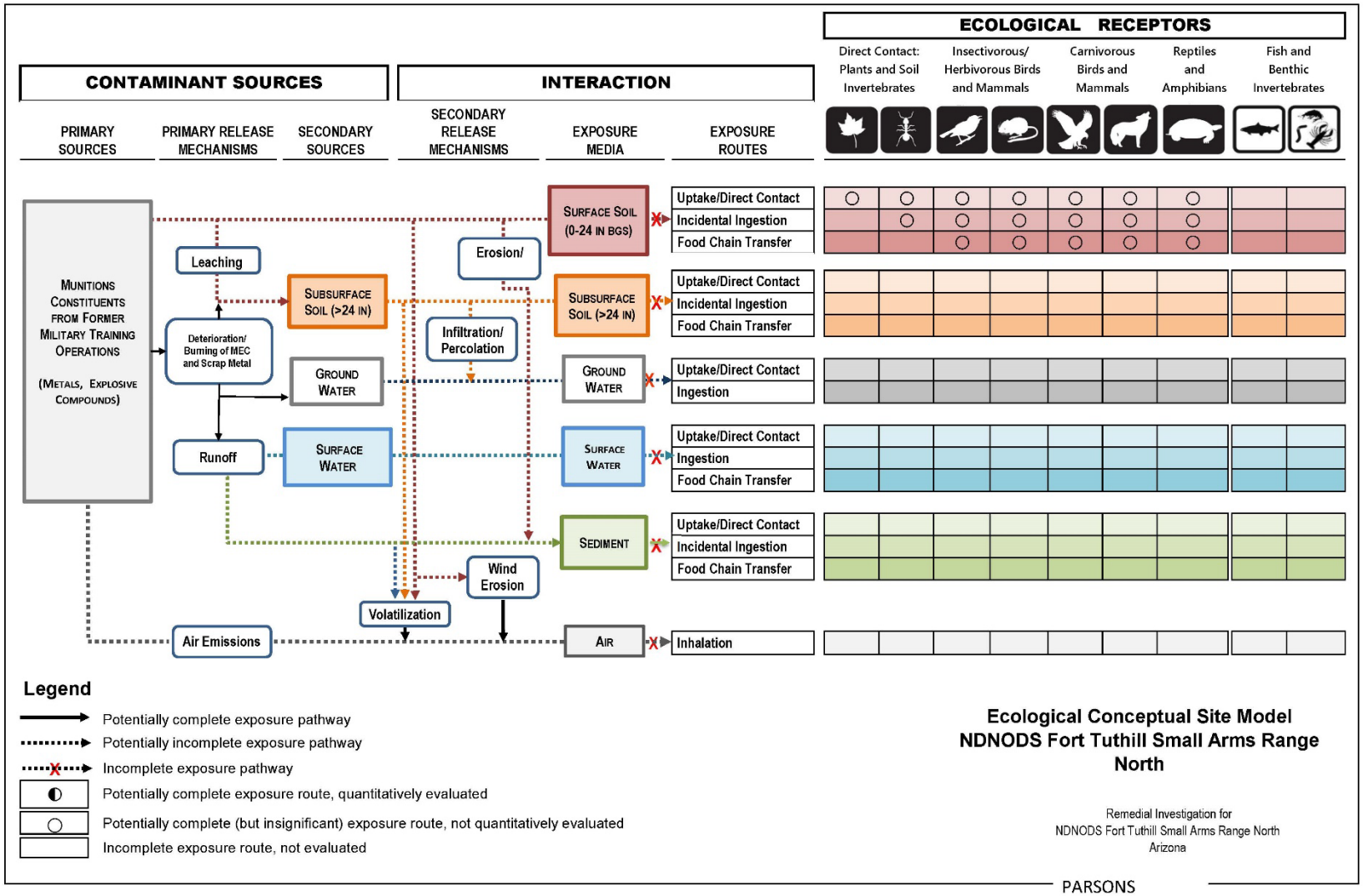


Figure 2.7 Conceptual Site Model – Ecological Exposure Pathways Diagram



2.8 PRELIMINARY IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND "TO BE CONSIDERED" INFORMATION

2.8.1 Response actions must identify and attain or formally waive applicable or relevant and appropriate requirements (ARARs) under federal and state laws (Engineer Regulation [ER] 200-3-1) (USACE, 2004). ARARs must be complied with to the extent practicable. Although the RI is not considered a response action, preliminary identification of chemical-specific, location-specific, and action-specific ARARs is conducted by the lead and support agencies during RI site characterization as required by the NCP. ARARs are used as a starting point to determine the protectiveness of a site remedy (USAEC, 2009).

2.8.2 As the RI/FS process continues, the list of ARARs will be updated, particularly as guidance is issued by state and federal agencies. As part of the preparation of this RI/FS, the Project Team engaged AZDEQ (via formal inquiry dated June 18, 2021) regarding identification of candidate ARARs. AZDEQ provided potential additional ARARs for consideration on August 3, 2021 (see Appendix K, Items 5 and 5a). ARARs will be used as a guide to establish the appropriate extent of site cleanup; to aid in scoping, formulating, and selecting proposed treatment technologies; and to govern the implementation and operation of the selected remedial alternative. As part of the FS, primary consideration should be given to remedial alternatives that attain or exceed the requirements of the identified ARARs. Throughout the CERCLA process, ARARs are identified and used by considering the following:

- Contaminants suspected or identified to be at the MRS;
- Chemical analysis performed or scheduled to be performed;
- Types of media (air, soil, groundwater, surface water, and sediment);
- Geology and other MRS characteristics;
- Use of MRS resources and media;
- Potential contaminant transport mechanisms;
- Purpose and application of potential ARARs; and
- Remedial alternatives considered for MRS cleanup.

2.8.3 Chemical-specific ARARs are promulgated health-based or risk-based numerical values that establish the acceptable amount or concentration of a chemical that may remain in, or be discharged to, the ambient environment. Risk-based screening levels (e.g., USEPA risk screening levels [RSLs]) are not considered chemical-specific ARARs because they are not promulgated. No chemical-specific ARARs have been identified for the NDNODS Fort Tuthill Small Arms Range North MRS given the absence of MC contamination identified during the SI and RI as well as the absence of criteria justifying additional MC sampling.

2.8.4 Location-specific ARARs generally are restrictions placed on the concentration of a hazardous substance or the conduct of activities solely because they are in special locations. No location-specific ARARs have been identified for the NDNODS Fort Tuthill Small Arms Range North MRS.

2.8.5 Action-specific ARARs are usually technology or activity-based requirements or limitations placed on actions taken with respect to remedial/removal actions, or requirements to conduct certain actions to address particular circumstances at a site. These actions include removal, decontamination, and/or control of such media. Action-Specific ARARs are presented in **Table 2.3**.

2.8.6 When ARARs do not exist for a particular chemical or remedial activity, other criteria, advisories, and guidance referred to as To Be Considered (TBC) are useful in designing and selecting a remedial alternative. No TBCs have been identified.

Table 2.3 Potential ARARs

Requirement	Citation(s)	Description	Applicability or Relevance
Chemical-Specific ARARs			
None – No MC contamination presence			
Location-Specific ARARs			
None			
Action-Specific ARARs			
RCRA, Subpart X	40 CFR 264.601	Environmental performance standards for treatment of munitions using consolidated shots at a designated open burning and open detonation location.	Waste material (such as deposition of explosives and metals in soil) resulting from MEC disposal activities will be characterized by soil sampling in accordance with requirements. This ARAR is applicable in the event any MEC removal alternative is implemented.

3.0 Project Technical Approach

3.1 OVERVIEW

3.1.1 The Technical Approach for this RI was based on the findings of previous investigations and other available historical information and was designed to obtain data to sufficiently characterize the presence or absence as well as nature and extent of MEC and MC contamination at the NDNODS Fort Tuthill Small Arms Range North MRS, and to evaluate potential hazards or risks related to MEC and MC identified in the preliminary CSM. Furthermore, the RI Technical Approach was planned to support the development of potential remedial alternatives where complete exposure pathways were identified.

3.1.2 The design for obtaining data included DGM surveys, intrusive investigation of anomalies, and potential collection of environmental soil samples. The specific processes and procedures used to conduct this investigation are detailed in the approved RI UFP-QAPP (Parsons, 2020), which was reviewed and accepted by the Project Team. These investigation methods are described in the following sections, while the results are presented in **Chapter 5**. A summary of the approaches for evaluating MEC and MC is provided in the following subchapters and is presented alongside the CSM in **Subchapter 2.6**.

3.2 MEC SAMPLING DESIGN

The primary components of the MEC sampling design for the RI at the NDNODS Fort Tuthill Small Arms Range North MRS involved DGM surveys utilizing the PDM8 sensor, intrusive investigation, and data evaluation as listed below. A more detailed look at the Visual Sample Plan (VSP) parameters used to guide the sampling design can be found in **Appendix A**.

- PDM8® DGM data were collected on 2-ft wide transect surveys spaced at approximately 150-ft intervals in the extended 2.36-inch bazooka rocket safety fan and 100-ft intervals in the historic small arms range, sufficient to provide 100% confidence for detection of the potential target areas at the MRS. No additional transects were necessary to delineate potential HUA boundaries. Data collected along transects was evaluated using VSP software and used to divide the MRS into HD areas (potential HUAs) and LD areas (potential LUAs or NEUs) based on the anomaly density analysis. As a result of the RI data collection effort, the entire 100-acre MRS was designated as an LUA. No HUAs or NEUs were identified (Appendix K, Item 2b HD/LD Map).

- Seven grids were surveyed in areas identified as HD (potential HUAs) in order to characterize potential MEC and, if present, the lateral and vertical extent of the MEC contamination (grids 1, 6, 7, 8, 9, 10, 12 on **Figure 3.1**). Five additional grids were surveyed in areas identified as LD (grids 2, 3, 4, 5, 11 on **Figure 3.1**) to confirm absence of MEC or significant MD in the non-HD area. The grids were surveyed using the PDM8® sensor. Grid anomalies were then intrusively investigated. Full DGM survey of the grids was conducted unless impeded by permanent structures or obstacles or identified as anomaly-saturated (Appendix E, FCR #1).

- Several HD areas were identified along the eastern edge of the expanded MRS near the refurbished former barracks area. These areas were "ground-truthed" following the DGM survey and were confirmed to be associated with the camping/parking/zipline area and include metal fencing, structures, numerous stored recreational vehicles and various other cultural interferences clearly not indicative of former training activities. In addition, this area is not within or near the suspected impact area nor where the two prior 2.36-inch bazooka rockets were identified. As such, this HD area did not warrant intrusive investigation or further consideration as an HUA (Appendix K, Item 2b HD/LD Map).

- Areas with low anomaly density (LD areas) were considered potential LUAs. LUAs were investigated in accordance with the approved Final UFP-QAPP (Parsons, 2020) and Preliminary MRS Characterization Memorandums, with the intent of refining and confirming the CSM, amount of MEC for the baseline risk assessment, and the boundary of any HUA and NEU areas. As previously noted, the entire 100-acre MRS was ultimately designated as an LUA (see Subsection 3.5).

- No areas were determined not to have potentially been used for training with explosively hazardous munitions. Therefore, designation of an NEU area or areas was not initially warranted during the RI.

3.3 MC SAMPLING DESIGN

3.3.1 The MC sampling approach at the NDNODS Fort Tuthill Small Arms Range North MRS was designed to characterize nature and extent of potential MC contamination in surface soil and determine if releases of MC from munitions activities have occurred that may pose a risk to human health and the environment. A multi-phased MC sampling approach was planned based on the expected identification of HUAs during the DGM and intrusive tasks. The primary components of the MC sampling design for the RI involved incremental sampling method (ISM) soil samples as listed below. Incremental soil sampling was conducted in accordance with SOP ENV-01, Soil Sampling found in the Parsons UFP-QAPP.

- Surface soil background samples were collected from areas not anticipated to have been affected by past military operations using incremental sampling methodology (ISM) to include 10 sampling units (SUs) (50 increments per 100-ft x 100-ft SU).
- Phase I surface soil samples were collected to determine whether there was evidence of a release of MC to surface soil. Since no HUAs were identified during the RI, four SUs were placed at grids where MD were identified during the intrusive investigation (Grids 1, 2, 5, and 7). The SUs were placed in areas most likely to demonstrate evidence of a release of MC. Each sample consisted of 50 increments collected from a 100-ft by 100-ft SU for analysis of explosives identified in Worksheet #15 of the UFP-QAAP (Parsons, 2020). One randomly selected SU (FT-SS-0-6-07) was collected in triplicate.
- Phase I sample results were evaluated to determine screening level exceedances and to determine if additional sampling was warranted. No explosives were detected in any of the four samples collected at the NDNODS Fort Tuthill Small Arms Range North MRS. Therefore, MC contamination is not present and additional Phase II surface soil and/or subsurface soil samples were not collected.

3.4 MUNITIONS AND EXPLOSIVES OF CONCERN CHARACTERIZATION

3.4.1 OVERVIEW

General MEC characterization tasks planned for this RI included conducting DGM surveys followed by intrusive investigation of subsurface sources. The following subchapters describe the conduct tasks, Geophysical System Verification (GSV), and MEC safety. **Table 3.1** summarizes the quantities of geophysical data collected at the NDNODS Fort Tuthill Small Arms Range North MRS. **Figure 3.1** shows the locations of geophysical data collection.

Table 3.1 Geophysical Data Collected

Survey	Total Collected	Comments
Transects		
DGM Survey with PDM8®	8.25 miles	Data used for anomaly density calculations. Transects covered MRS with spacing 100 ft and 150 ft depending on location, in accordance with UFP-QAPP.
Grids – DGM with PDM8®		
HD Grids (Grids 1, 6, 7, 8, 9, 10, 12	1.61 acres	6 grids (100 ft x 100 ft), 1 grid (25 ft x 400 ft)
LD Grids (Grids 2, 3, 4, 5, and 11)	1.15 acres	5 grids (100 ft x 100 ft)

Note – Grid 12, located in the designated HD Area, was elongated following Project Team discussions in order to capture two adjacent, small, isolated areas of elevated anomaly density.

3.4.2 GEOPHYSICAL SYSTEM VERIFICATION AND TARGET SELECTION CRITERIA

3.4.2.1 A Geophysical System Verification (GSV) process was implemented at the NDNODS Fort Tuthill Small Arms Range North MRS to demonstrate that the instruments and data collection strategies selected for the MRS functioned as intended for the duration of the field investigation. Within this process an Instrument Verification Strip (IVS) was used to verify the proper functioning of the geophysical systems used during the project. An IVS was constructed at the NDNODS Fort Tuthill Small Arms Range North MRS to accomplish the following goals:

- Confirm that the PDM8® sensor used for geophysical data collection was functioning correctly, both at the start of the project and twice daily throughout the project;
- Demonstrate dynamic location repeatability over the IVS items;
- Confirm that detection survey measurement quality objectives in the UFP-QAPP are appropriate and achievable, and;

3.4.2.2 Details on IVS construction and the result of initial IVS testing for the PDM8® are contained in the IVS Technical Memorandum (**Appendix A**).

3.4.2.3 Based on the initial IVS background noise levels described in the Target Selection Memorandum (**Appendix A**), target selection on transects was performed using a profile peak picking algorithm with a threshold of 32 counts. This threshold was ten times the RMS noise level of 3.2 counts measured on the noise line during initial IVS testing, as stated in the UFP-QAPP as the method for determining the target selection threshold. Grid based targets were selected using grid specific noise levels to identify grid specific thresholds as described in the Target Selection Memorandum (**Appendix A**), with a target selection threshold of ten times the RMS noise levels identified for each grid.

3.4.2.4 Within complete coverage grids, saturated response areas were defined with polygons. Within these areas, intrusive sampling locations were chosen so that there was roughly one anomaly per 225 square feet (15'x15' area). These locations were chosen at peaks in responses, or within large areas of elevated response.

3.4.2.5 Target lists were compiled for the transect data and the grid-based data. Picked transect targets were only used for the delineation of target areas using VSP. The QC (quality control) Geophysicist confirmed that all QC seeds had been detected as required in the UFP-QAPP prior submittal of any final full-grid data to the USACE. Upon QC seed confirmation, target lists were submitted to the USACE Geophysicist for confirmation that all quality assurance seeds were detected. Additional detail regarding the target selection and the process used to determine the target selection threshold is contained in the Target Selection Technical Memorandum (**Appendix A**).

3.4.3 MEC INVESTIGATION

3.4.3.1 DGM TRANSECT SURVEYS

3.4.3.1.1 The proposed transect coverage for the NDNODS Fort Tuthill Small Arms Range North MRS was designed to identify a 367-ft radius target area with an average anomaly density of 200 anomalies/acre above background (assumed as 50 anomalies/acre) with 100% confidence per VSP. To achieve these objectives, DGM data were collected across the MRS at approximately 150-ft intervals in the safety fan and 100-ft intervals in the small arms range. The DGM transect data were collected with the PDM8® paired with differential GPS along 8.25 miles of transects (**Table 3.1**).

3.4.3.1.2 Once transect DGM data collection was complete, the data were processed and evaluated to identify anomalies with responses above the target selection criteria. The DGM data were analyzed to separate the MRS into LD and HD areas using VSP to facilitate sample planning and results analysis. Analysis of the data collected using the Post-Survey Probability of Traversal tool in VSP indicated that almost any target area meeting the assumed 367-ft radius requirement in areas where ROE was granted would have been traversed, with the exception of Air Force property in the southern portion of the site where no ROE was available. Based on VSP analysis of the collected data, the probability of traversal of a theoretical target area in the areas surveyed was calculated to be 100% within accessible portions of the MRS.

3.4.3.2 TRANSECT ANALYSIS AND DGM GRID PLACEMENT

3.4.3.2.1 The primary objectives of the transect data analysis were to confirm that the collected transect data were sufficient to identify high use areas with 100% confidence, create a contour map of anomaly density for the MRS (**Figure 3.1**), differentiate between areas of low anomaly density representing background conditions in areas considered to be relatively unaffected by potential concentrated munitions use and areas of high anomaly density potentially representing MEC-contaminated HUAs, identify locations for low density area DGM grids to be used to confirm that MEC is not a significant hazard in background areas, and identify locations and sizes for high density area DGM grids to be used to determine the nature and extent of MEC contamination in potential target areas.

3.4.3.2.2 As shown in **Figure 3.1**, calculated across-site densities range from approximately 0 anomalies per acre (APA) to over 4500 APA. A total of 3 HD areas (HD1, HD2, and HD3a/3b/3c) were identified, representing potential HUAs (Appendix K, Item 2b HD/LD Map). Based on the results of the transect survey the Project Team selected 7 grids (six 100 ft by 100 ft and one 25 ft by 400 ft), totaling approximately 1.61 acres, to characterize the HD areas (Grids 1, 6, 7, 8, 9, 10, and 12). The remaining LD area was characterized using five grids (Grids 2, 3, 4, 5, 11) totaling roughly 1.15 acres of (100 ft by 100 ft) grids. The grid placements are depicted on **Figure 3.1**.

3.4.3.3 DGM GRID SURVEYS AND ANOMALY SELECTION

3.4.3.3.1 The grids were surveyed using the PDM8® with fiducial positioning to identify subsurface anomalies potentially indicative of MEC. The method used to conduct DGM surveys is described in the approved Final UFP-QAPP (Parsons, 2020). The anomaly selection criterion used for the PDM8® data is documented in the Target Selection Technical Memorandum (**Appendix A**). Anomalies were selected as described in the UFP-QAPP and Target Selection Technical Memorandum. A detection survey Data Usability Assessment (DUA) (**Appendix A**) was completed using the three-step process described in Worksheet #37 of the UFP-QAPP following the Project Team's acceptance of transect and grid target lists.

3.4.3.3.2 Data QC results are summarized in the project QC database (daily sensor testing and general dataset information) or in Geosoft databases and maps (**Appendix A** digital data deliverable). QC seed results were evaluated prior to submittal of the dig list, and the USACE evaluated validation seed results and other pertinent QC data prior to acceptance of the list.

3.4.3.4 ANOMALY REAQUISITION AND INTRUSIVE INVESTIGATION

3.4.3.4.1 Intrusive investigation of anomalies identified in the grid-based data was used to determine the nature and extent (vertical and horizontal) of MEC contamination. Intrusive investigation results were recorded including the characteristics of sources (i.e., size, shape, metal composition) recovered from anomalies identified by PDM8®. For all excavations, the intrusive team navigated to the location of each DGM anomaly selected for investigation using fiducial positioning. Once the location was positioned, a marker flag was placed at the location and a 1-m radius around the flag was resurveyed using the PDM8® to confirm the selected anomaly.

3.4.3.4.2 Following reacquisition, anomalies were excavated with hand tools by qualified UXO technicians. The intrusive team began each excavation in the location of highest response and continued the excavation until the reacquired PDM8® response had either been removed or characterized around the 1-m search radius. Reacquisition locations were evaluated according to the required accuracy for the survey performed (i.e., 80 cm acceptable offset for DGM data). The results of the intrusive investigation were recorded on the project dig sheets. The results are discussed in **Chapter 5**.

3.4.4 MUNITIONS AND EXPLOSIVES OF CONCERN SAFETY

3.4.4.1 MUNITION WITH THE GREATEST FRAGMENTATION DISTANCE

Based on historical data, previous investigations, and the discovery and disposal of the MEC recovered in 2017, the munition with the greatest fragmentation distance (MGFD) for the NDNODS Fort Tuthill Small Arms Range North MRS is the Rocket, 2.36-inch, HEAT, M6 Series. The MGFD was presented in the DoD Explosives Safety Board (DDESB)-approved Explosives Site Plan (ESP) (Parsons, 2020).

3.4.4.2 MINIMUM SEPARATION DISTANCE

The minimum separation distance (MSD) is a personnel protective distance based on the characteristics of the selected MGFD and Department of the Army Pamphlet 385 63 (Department of the Army, 2012). The specific MSDs for the NDNODS Fort Tuthill Small Arms Range North MRS were presented in the DDESB-approved ESP (Parsons, 2020) and the approved Final UFP-QAPP (Parsons, 2020). MSDs for unintentional detonations were established for personnel based on the hazardous fragment distance (HFD) of 142 ft for the appropriate MGFD. MSDs for intentional detonations were also established for disposal operations, based on the maximum fragmentation distance, horizontal for the MGFD.

3.4.4.3 EXCLUSION ZONES

Exclusion zones (EZs) were established during the RI to protect the public and nonessential personnel from intentional and unintentional detonations. The size of the EZ was determined based on the calculated MSD for the known or assumed MGFD. These EZ distances were enforced during all intrusive operations at the NDNODS Fort Tuthill Small Arms Range MRS.

3.4.5 UXO/MPPEH MANAGEMENT AND DISPOSITION

No items excavated during intrusive operations were blow-in-place (BIP). Complete details are provided in **Appendix B**.

3.5 MUNITIONS CONSTITUENT CHARACTERIZATION

3.5.1 OVERVIEW

The 2012 SI recommended NFA for MC for the MRS based on lead results collected from soil within the small arms range below screening values (400 mg/kg). In accordance with the accepted Final UFP-QAPP (Parsons, 2020), MC characterization tasks planned for this RI included the collection of ISM soil samples solely from within post-intrusive designated HUAs (not from within LUAs or NEUs) followed by the analysis of those samples for explosives and related munitions composition metals. However, due to the absence of MEC findings throughout both the surface reconnaissance and intrusive investigation phase of the fieldwork and only sparse presence of MD, no HUAs were identified. As such, the criteria triggering implementation of MC sampling was not met. However, following Project Team discussions to include Arizona DEQ, MC samples were collected and analyzed for explosives in SUs coincident with the four grid locations where MD was recovered. No detectable explosives concentrations were identified. The MC characterization presented in the following subchapters discusses the MC sampling conducted and associated rationale.

3.5.2 MUNITIONS CONSTITUENT INVESTIGATION

3.5.2.1 The MC sampling conducted during this RI was intended to re-address the SI recommendation of NFA for MC which was based on ROE-limited access to portions of the MRS and was strictly focused on small arms range concerns (lead). In light of subsequent concerns and reconsideration of the MRS as a potential munitions (2.36-inch bazooka rockets) training area, the initial RI strategy was to sample soil from within any designated HUAs to evaluate potential presence as well as characterize nature and extent of potential MC contamination. The ISM sampling technique was identified and approved to collect soil samples. The ISM provides a more accurate measure of the mean concentration of contaminants in a given volume of soil (the “sampling unit, or SU) by providing reproducible, scientifically defensible data. ISM sampling involves defining one or more SUs to be sampled within an area, from which multiple “sample increments” are collected and composited into a single “incremental sample” for each SU. The process for collecting incremental samples involves designating the incremental sample collection grid, determining the sampling interval, selecting the sample collection origin, and collecting the sample increments. As noted above, no HUAs were identified within the MRS thus MC sampling criteria was not met. However, four samples were collected within four SUs where MD were recovered during intrusive investigations.

3.5.2.2 Four ISM surface soil samples (one in triplicate) were collected from SUs collocated with DGM grids where MD were found (grids 1, 2, 5, and 7). Fifty increments were collected from each 100ft by 100ft SU from 0 to 6 inches bgs and submitted for analysis of explosives. The locations of these samples (FT-SS-0-6-01, FT-SS-0-6-02, FT-SS-0-6-05, and FT-SS-0-6-07) are shown on **Figure 3.2**.

3.5.2.3 Prior to the confirmation of the absence of HUAs within the MRS, ten background ISM surface (0-6 inches bgs, or 0-3 inches bgs where there was shallow rock/auger refusal) soil samples (FT-SS-BKG-0-6-01 through FT-SS-BKG-0-3-10) were collected to determine the naturally occurring concentrations of metals outside the boundary of the NDNODS Fort Tuthill Small Arms Range North MRS (**Figure 3.2**). The background incremental samples were analyzed for MC metals (antimony, copper, lead, and zinc) and explosives. A field triplicate was collected for sample FT-SS-BKG-0-3-03. Background samples were also analyzed for explosives in order to provide further evidence that the background locations were not affected by munitions activity.

Table 3.2 ISM Soil Sampling Results

Grid Number	MEC Presence	MD Presence	Explosives (8830B) Detections
1	None	Saturated grid. Numerous lead bullets/copper jackets, cartridge casings, unidentifiable munitions fragments	ND
2	None	Numerous lead bullets/copper jackets, cartridge casings, munitions fragments to include two suspect 57mm recoilless rifle fragments	ND
5	None	Several lead bullets/copper jackets and single suspect 60mm HE mortar fragment	ND
7	None	Several lead bullets/copper jackets and three 60mm HE mortar fragments to include tail fins	ND

3.5.3 ANALYTICAL LABORATORY AND ANALYSES

3.5.3.1 All samples were shipped to APPL Labs, Clovis, California for analysis. Analytical data were verified using editorial and technical reviews. Laboratory extraction and analytical methods were conducted in accordance with the approved Final UFP-QAPP (Parsons, 2020). Metals analyses were not conducted due to the extremely high density of non-munitions related cultural debris coupled with prior SI recommendation of NFA for MC.

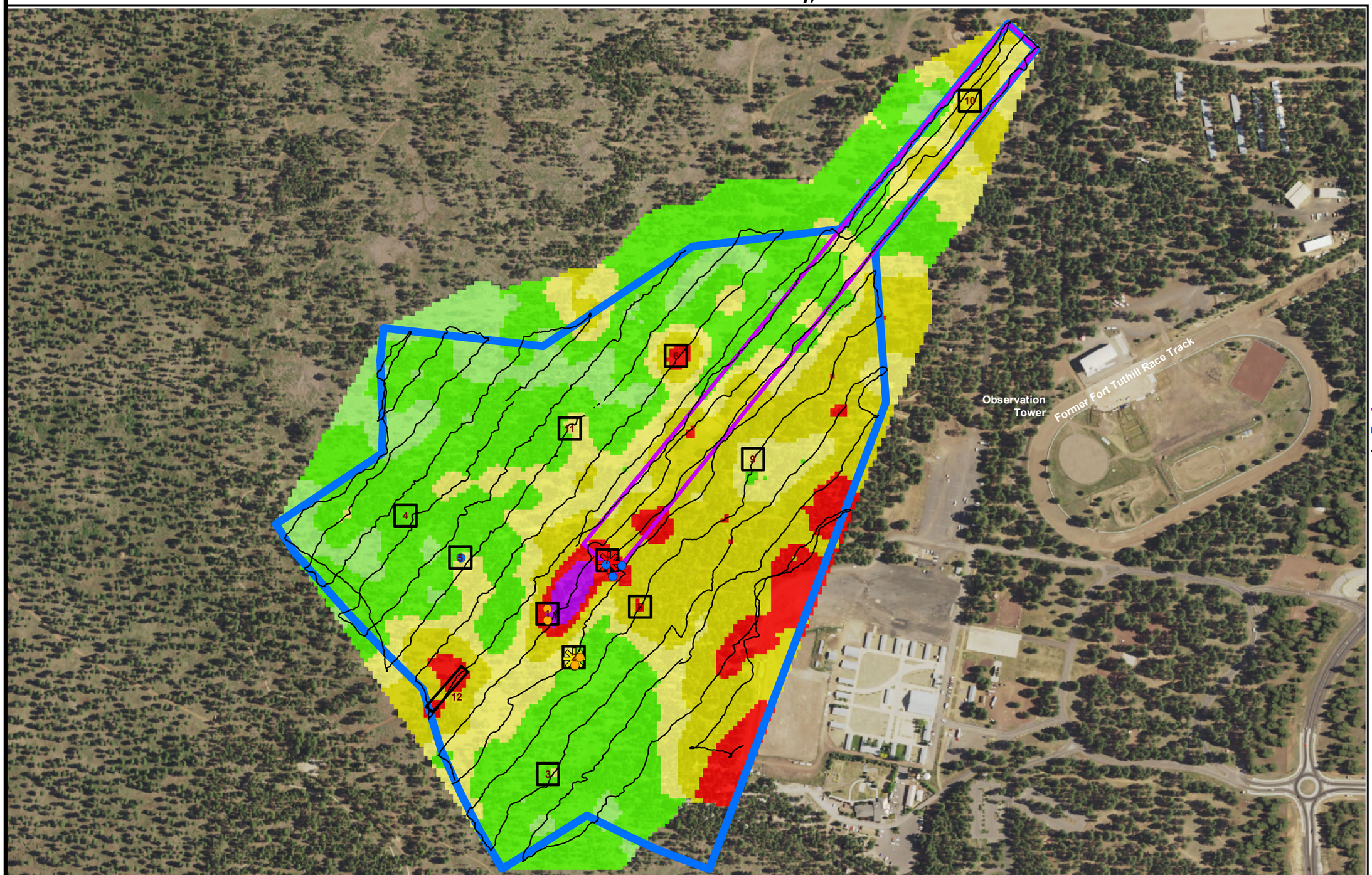
3.5.3.2 The analytical data generated during the sampling effort were validated by the Parsons Project Chemist in accordance with the requirements identified in the approved Final UFP-QAPP (Parsons, 2020). The validation included requirements in DoD Quality System Manual (QSM) Version 5.3. Data validation reports were generated by the project chemist for all data packages and are provided in **Appendix C** of this report. The validation reports concluded that all data are usable.

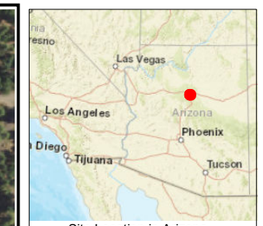
3.5.4 DEVELOPMENT OF BACKGROUND CONCENTRATIONS

Background samples were collected and analyzed for MC metals (antimony, copper, lead, and zinc) and explosives during Phase I of the RI field effort. Background concentrations of metals are due to either natural or anthropogenic sources and are not DoD-related contaminant concentrations. However, background threshold values were not established for metals, because no biased metals analysis was subsequently performed. An HUA was not identified and, therefore; MC sampling was not required in accordance with the approved Final UFP-QAPP (Parsons, 2020). However, the Project Team opted to collect samples in DGM grids where MD was present and analyzed these samples for explosives constituents. Background samples were also sampled for explosives to provide further evidence that the background locations were not affected by historic munitions activity. All four ISM soil samples were free of detectable explosive contamination.

Figure 3.1
Actual Transect and Grid Locations
NDNODS Fort Tuthill Small Arms Range North
Site ID: AZHQ-005-R-01
Coconino County, Arizona

PARSONS





Site Location in Arizona

Legend

- 2.36-inch Practice Round Found in 2000
- 2.36-inch Practice Round Found in 2017
- 57mm HE Recoilless Rifle Round MD
- 60mm HE Mortar MD
- Small Arms Range North
- Investigation Area
- DGM Transect
- Grid (0.25-acre nominal size)

Estimated Anomalies/Acre

- 0 - 50
- 50.00000001 - 500
- 500.0000001 - 1,000
- 1,000.000001 - 2,000
- 2,000.000001 - 3,000
- 3,000.000001 - 4,600

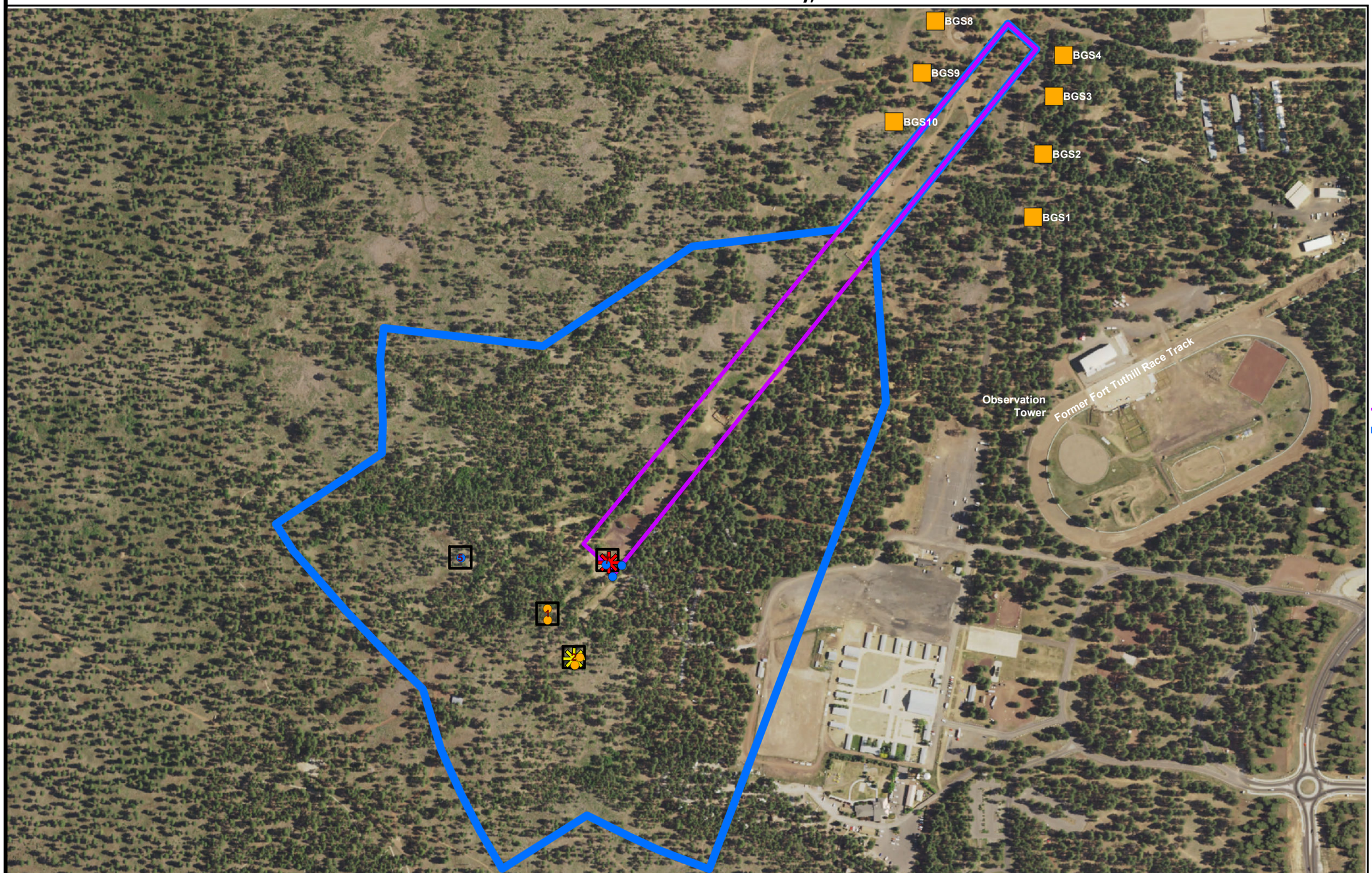
80 40 0 80
Meters

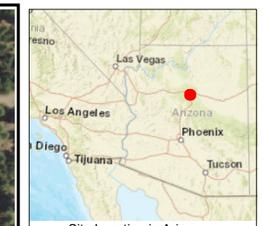
N

PROJECT NUMBER:
100087.0538.110208.03004
June 2021

Figure 3.2
Actual MC Sample Locations
NDNODS Fort Tuthill Small Arms Range North
Site ID: AZHQ-005-R-01
Coconino County, Arizona

PARSONS





Site Location in Arizona

Legend

- Background Sample Grid Location (100' x 100')
- 2.36-inch Practice Round Found in 2000
- 2.36-inch Practice Round Found in 2017
- 57mm HE Recoilless Rifle Round MD
- 60mm HE Mortar MD
- Small Arms Range North
- Investigation Area
- MC Sample Location

80 40 0 80
Meters

N

PROJECT NUMBER:
100087.0538.110208.03004
June 2021

4.0 Data Quality Assessment

4.1 DATA NEEDS

The preliminary CSM for the NDNODS Fort Tuthill Small Arms North MRS indicated that MEC, in the form of UXO, may have been present in the MRS based on the single, potentially practice, bazooka rocket recovered during recent (2017) construction activities within the MRS and a practice rocket found by maintenance staff in 2000. With regard to MC, the preliminary CSM indicated that explosives and MC metals (antimony, copper, lead, and zinc) may have been released to surface and subsurface soil within HUAs. The project objectives for the RI at the NDNODS Fort Tuthill Small Arms Range North MRS were to obtain data to sufficiently characterize the presence or absence as well as nature and extent of MEC and MC contamination within the MRS, and to evaluate potential hazards or risks related to identified contamination. The data needs for this project were reviewed by the Project Team and include collecting adequate data to assess MEC and MC contamination in the soil. The Data Quality Objectives (DQOs) associated with the data to be collected during the RI were developed by the SPP Team and included in the approved Final UFP-QAPP (Parsons, 2020).

4.2 DATA QUALITY OBJECTIVES

4.2.0.1 DQOs are qualitative and quantitative statements that specify the quality and level of data required to support the decision-making processes for a project. The MEC DQOs developed for the project include the environmental problem, the related decisions that need to be made, the type and quantity of data, and level of data quality needed to ensure that those decisions are based on sound scientific data. The overall goal of this project is to obtain acceptance of an RI/FS, Proposed Plan, and Decision Document in accordance with CERCLA, as amended, and DoD, Army and USACE regulations and guidance. The information collected to meet the DQOs will be sufficient to characterize the presence or absence as well as nature and extent of any MEC and/or MC and assess human health and ecological risks present at the MRS to facilitate development of the FS.

4.2.0.2 DQO elements are developed during project planning sessions using a systematic planning process (SPP). Examples of SPP include the Environmental Protection Agency (EPA)'s seven-step DQO process defined in EPA Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4, EPA/240/B-06/001, February 2006; Intergovernmental Data Quality Task Force Uniform Federal Policy-Quality Assurance Project Plans Manual; and the USACE Technical Project Planning Process (TPP), EM 200-1-2, February 29, 2016. Worksheet #11 of the approved Final UFP-QAPP (Parsons, 2020) describes the EPA seven-step process for the MEC and MC DQOs for the NDNODS Fort Tuthill Small Arms Range North MRS. The status of the MEC and MC DQOs following completion of the RI are summarized in **Sections 5.1.2** and **5.2.2**, respectively. The status of the geophysical MQOs are described in **Section 4.3**.

4.3 MEASUREMENT PERFORMANCE CRITERIA/MEASUREMENT QUALITY OBJECTIVES

4.3.1 MEC CHARACTERIZATION QUALITY CONTROL

The field operations for this project involved multiple elements, or "definable features of work." **Tables 4.5** and **4.6** summarize the measurement performance criteria (MPCs) and measurement quality objectives (MQOs) that were established for the definable features of work associated with the MEC-related tasks conducted during the RI. The quality of these procedures and the related results have been evaluated for compliance with DQOs through a review of overall Precision, Accuracy, Representativeness, Comparability, and Completeness (PARCC). Note that MPCs and MQOs are required to indicate that the relevant data are of adequate quality to support project decisions; however, not all definable features of work are related to project decisions and for this reason not all definable features of work have related MPCs. The full list of MPCs and MQOs evaluated for MEC is included in **Tables 4.5** and **4.6**, which include a pass/fail decision for each MPC and MQO. Failures noted in the table are described in more detail below.

4.3.1.1 GEOPHYSICAL INVESTIGATION QUALITY CONTROL

The following MPC/MQO failures were noted for the geophysical data collected during the RI. The Root cause analyses (RCAs) are located in **Appendix D**:

- MQO for detection survey performance is offset between selected anomaly location and seed item location is ≤ 0.5m + ½ line spacing (0.8 m total), from as-built position (x, y). During initial collection of Grid 3 on October 13, 2020, the nearest peak response was only 0.003m within the detection offset tolerance. Initial Latency/Lag correction placed it 0.03 m outside of the detection tolerance. The seeding team was sent to the seed location to confirm that the seed item was still present. Once the seed location was confirmed, the team remapped Grid 3 on October 15, 2020. The seed position was offset in the same direction as previously, but within tolerance with 0.52 m of offset. The most likely cause for this failure was accumulated positioning error in the fiducial survey due to changes in speed between fiducial marks, variations in latency/lag correction, and error in the initial seed position. RCA-01 accepted, two corrective actions were applied. 1) The field team was briefed on fiducial positioning best practices, including maintaining constant speed between fiducial marks, makings sure tapes are flat and straight, and making sure that survey lanes are collected in straight lines. 2) After this briefing, DGM Grid 3 was recollected on October 15, 2020.

The information pertaining to geophysical QC, including the IVS reports, dig sheets, Microsoft Access Database, and raw geophysical data for the RI are included as attachments within **Appendix A**.

4.3.1.2 INTRUSIVE INVESTIGATION QUALITY CONTROL

Each anomaly selected for intrusive investigation was resolved. The intrusive team leader documented the source of the anomaly and verified that the anomaly had been adequately characterized. A final reading was taken with the PDM8® at the anomaly location to confirm that the area had been cleared. Any remaining response at an anomaly location was investigated unless the source was identified (i.e., fencepost). In addition to the post-intrusive checks by the intrusive team; the UXO QC Specialist (UXOQCS) checked at sufficient excavations to confirm that they were properly resolved and that the MPC for confirming removal (**Table 4.5**) had passed. A geophysicist reviewed the intrusive results and compared the intrusive teams' findings with the geophysical anomalies selected from the DGM data. The intrusive information collected for the NDNODS Fort Tuthill Small Arms Range North MRS has been determined to be sufficient to determine both presence or absence as well as the nature and extent of the MEC hazard in the MRS.

4.3.2 MC CHARACTERIZATION QUALITY CONTROL

4.3.2.1 Sampling activities were conducted in accordance with the approved Final UFP-QAPP (Parsons, 2020). The UFP-QAPP addressed the DQOs, analytical methods, specific quality assurance (QA) and QC activities, laboratory requirements, and data validation activities required to achieve the MC data quality goals of the project. **Tables 4.7** and **4.8** summarize the MPCs in terms of data quality indicators (i.e., accuracy, sensitivity, representativeness, completeness, and comparability) that were established for the MC-related tasks conducted during the RI. The full list of MC-related MQOs evaluated for the RI is included in **Table 4.9**.

4.3.2.2 The sampling procedures and laboratory results have been evaluated for compliance with DQOs and MPCs through a qualitative and quantitative evaluation of environmental data to determine if the project data are of the right type, quality, and quantity to support the decisions that need to be made. Based on this review, the validated data indicated that the laboratory correctly performed the analyses. None of the data was qualified as rejected, therefore, all data is considered usable. The results, along with data usability is summarized in the Data Validation Report found in **Appendix C**.

4.4 DEPARTURES FROM PLANNING DOCUMENTS

The NDNODS Fort Tuthill Small Arms Range North MRS was investigated in accordance with the approved Final UFP-QAPP (Parsons, 2020) with the following deviations:

- The Final UFP-QAPP, Worksheet 12, Table 12.1, MPC 10, Anomaly Resolution specifies "100% excavation in representative grids." A Field Change Request (FCR) was submitted requesting for grids with significant clutter including more than 150 targeted anomalies per grid (~100 ft by100 ft) area, intrusively investigate a representative subset of DGM anomalies instead of investigation of 100% of DGM anomalies. The changes described in this FCR apply to intrusive investigations in Grids 1, 7, and 12. This FCR was approved by USACE and ARNG.

- The Final UFP-QAPP, Worksheets 10 and 11 indicated that MC contamination would potentially be present in high use areas (HUAs) only and not expected in LUAs or NEUs. Concentrations of MC in environmental media should be proportional to the amount of munitions related activity that occurred in an area. There is a low probability that contamination will be detected unless the area was heavily used. Therefore, the MC investigation was planned at the HUAs, as these are the areas with the greatest likelihood of a release of MC to environmental media. Therefore, in Worksheets 10, 11, and 17 MC sampling was planned at HUAs for explosives and metals (antimony, copper, lead, and zinc). However, during the RI investigation no HUAs were identified. Therefore, sampling units (SUs) were not able to be placed in DGM grids within an HUA. Even though MC contamination is not expected in LUAs, four ISM SUs were placed coincident with all four DGM grids in which MD was found (grids 1, 2, 5, and 7) and analyzed for explosives. These samples were not analyzed for metals since there was not a HUA identified and there was a significant amount of non-munitions-related debris in these grids.

No other departures from planning documents occurred with regard to the RI performed at the NDNODS Fort Tuthill Small Arms Range North MRS. Additional details in fieldwork variances are located in **Appendix E**.

Table 4.1 Method Measurement Performance for Metals in Soil (SW6020B)

Matrix:	Soil (ISM)
Analytical Group or Method:	Trace Metals by Inductively Coupled Plasma/Mass Spectrometry (SW6020B)
Concentration Level (if applicable):	Not applicable

Data Quality Indicator (DQI)	QC Sample or Measurement Performance Activity	Measurement Performance Criteria
Overall accuracy/bias (contamination)	Blanks	No target analyte concentrations >= 1/2 limit of quantitation (LOQ)
Overall Precision	Field Triplicate	Relative Percent Difference (RPD) <= 35%
Analytical Precision (laboratory)	Lab Control Sample Duplicate	RPD <= 20%
Analytical Accuracy (laboratory)	Low Verification Standard	80 - 120%
Analytical Accuracy (laboratory)	Lab Control Sample	Antimony: 72 - 124%
		Copper: 84 - 119%
		Lead: 84 - 118%
		Zinc: 82 - 119%
Analytical Accuracy/Bias (matrix interference)	Matrix Spike Duplicate	RPD <= 20%
Analytical Accuracy/Bias (matrix interference)	Serial Dilution	±10% D
Analytical Accuracy (matrix interference)	Post Spike	80 - 120%

Table 4.2 Method Measurement Performance for Nitroaromatics and Nitramines in Soil (SW8330B)

Matrix:	Soil
Analytical Group or Method:	Nitroaromatics and Nitramines by High-performance liquid chromatography (HPLC) (SW8330B)
Concentration Level (if applicable):	Not applicable

Data Quality Indicator (DQI)	QC Sample or Measurement Performance Activity	Measurement Performance Criteria
Overall accuracy/bias (contamination)	Blanks	No target analyte concentrations >= 1/2 LOQ
Analytical Precision (laboratory)	Confirmation Column Difference	RPD <= 40%
Overall Precision	Field Triplicates	RPD <= 35%
Analytical Accuracy (laboratory)	Lab Control Sample	1,3,5-Trinitrobenzene: 80 - 116%
		1,3-Dinitrobenzene: 73 - 119%
		2,4,6-Trinitrotoluene: 71 - 120%
		2,4-Dinitrotoluene: 75 - 121%
		2,6-Dinitrotoluene: 79 - 117%
		2-Amino-4,6-dinitrotoluene: 71 - 123%
		2-Nitrotoluene: 70 - 124%
		3-Nitrotoluene: 67 - 129%
		4-Amino-2,6-dinitrotoluene: 64 - 127%
		4-Nitrotoluene: 71 - 124%
		Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX): 67 - 129%
		Nitrobenzene: 67 - 129%
		Nitroglycerin: 73 - 124%
		Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX): 74 - 124%
		Pentaerythritol tetranitrate: 72 - 128%
		Tetryl: 68 - 135%

Data Quality Indicator (DQI)	QC Sample or Measurement Performance Activity	Measurement Performance Criteria
Analytical Precision (laboratory)	Lab Control Sample Duplicate	RPD <= 20%
Analytical Accuracy (matrix interference)	Matrix Spike	1,3,5-Trinitrobenzene: 80 - 116%
		1,3-Dinitrobenzene: 73 - 119%
		2,4,6-Trinitrotoluene: 71 - 120%
		2,4-Dinitrotoluene: 75 - 121%
		2,6-Dinitrotoluene: 79 - 117%
		2-Amino-4,6-dinitrotoluene: 71 - 123%
		2-Nitrotoluene: 70 - 124%
		3-Nitrotoluene: 67 - 129%
		4-Amino-2,6-dinitrotoluene: 64 - 127%
		4-Nitrotoluene: 71 - 124%
		Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX): 67 - 129%
		Nitrobenzene: 67 - 129%
		Nitroglycerin: 73 - 124%
		Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX): 74 - 124%
		Pentaerythritol tetranitrate: 72 - 128%
		Tetryl: 68 - 135%
Analytical Accuracy/Bias (matrix interference)	Matrix Spike Duplicate	RPD <= 20%
Analytical Accuracy	Surrogate	1,2-Dinitrobenzene: 78 - 119%

Table 4.3 Measurement Performance Criteria for MEC-Related Tasks and Status Following Remedial Investigation

Measurement	Data Quality Indicator(s)	Measurement Performance Criteria	Activity Used to Assess Performance	Status Following Remedial Investigation
Site Preparation				
1. Accessibility	Completeness	All areas inaccessible to investigation or inaccessible to use of proposed geophysical systems are identified in a geographic information system (GIS) or the Geophysical database.	Parsons will visually inspect the site and/or review the GIS/Geophysical database	Pass
Sampling Design				
2. Planned survey coverage (Preliminary MRS Characterization)	Representativeness/ Completeness	Planned, initial transect spacing will be sufficient to detect high use areas with nominal transect spacing of 150 ft or less throughout the survey area.	QC geophysicist reviews VSP output.	Pass
3. Detection threshold (transects & grids)	Sensitivity	A detection threshold of 10 times the site-specific background noise will be used for the transect and grids using the PDM8®. The thresholds are subject to change based on instrument verification strip (IVS) results.	1) Review of sampling design 2) Initial verification at IVS 3) Background analysis prior to VSP analysis	Pass
Data Acquisition				
4. Positioning requirement (locating sampling grids	Accuracy	Actual positions must be within 10 meters of planned positions unless documented by obstructions within the planned grid.	Review of sampling design compared to actual survey location. (QC Geophysicist and lead agency oversight	Pass
5. Survey coverage: maximum speed on transect (analog)	Accuracy/ Completeness	98% ≤ 3 miles/hour. Using distance and time per section.	QC geophysicist/lead agency (or designee) oversight	Pass
6. Survey coverage (transects)	Accuracy/ Completeness	100% of accessible planned transects lengths are sampled[(1)].	Course over ground is recorded and evaluated, obstacles larger than ½ transect spacing noted and positioned.	Pass
7. Survey coverage (grids)	Accuracy/ Completeness	100% of specified acreage is surveyed.	Data validation	Pass
8. QC seeding (DGM grids only)	Accuracy/ Completeness	(High density (HD) Area Characterization) Contractors will place blind QC seeds at the rate of 1 to 3 seed/system/day.	Lead agency verifies all QC seed failures are explained and corrective action implemented	Pass
Anomaly Resolution				
9. Anomaly density estimates (assessed during intrusive investigations associated with population testing)	Accuracy/ Representativeness	Contiguous sub-areas (e.g. grids) within Target Area(s) will be mapped, and all anomalies meeting the project-specific detection threshold will be identified for excavation. The anomaly density in each sub-area (grid) will not differ from that predicted by more than +50% or -30%.	Total number of anomalies divided by the grid area will be compared to the anomaly density predicted from geostatistical anomaly density analyses (i.e. Kriging of transect data) for that location.	Pass
10. Anomaly resolution (DGM and analog)	Accuracy	HD Area Characterization: 100% excavation in representative grids. Excavation must continue vertically until anomaly is resolved, source identified, or other obstruction encountered. An FCR was approved changing "100% excavation in representative grids" to "100% excavation in representative grids, with a subset of anomalies investigated in grids with significant non-munitions clutter with USACE/ ARNG concurrence".	QC Geophysicist (or designee) verifies	Pass with Grids 1, 7, and 12 utilizing the FCR.
11. Anomaly resolution (DGM and analog)	Completeness	All items within 1m laterally and within the threshold depth must be recovered for each flag unless the source can be documented.	QC Geophysicist (or designee) verifies	Pass
No Evidence of Use Area Confirmation				
12. NEU Confirmation	Representativeness/ Completeness	Well-developed CSM, confirmed by RI results, showing no evidence of munitions use.	Data Usability assessment (DUA)	Pass

1 Actual transect coverage will be evaluate using VSP to determine whether any inaccessible areas are large enough to impact the detection of a 2.36-inch rocket impact area.

Table 4.4 Measurement Quality Objectives for MEC-Related Tasks and Status Following Remedial Investigation

Measurement Quality Objective	Frequency	Acceptance Criteria	Failure Response/Corrective Action	Status Following Remedial Investigation
Site Preparation				
Construct IVS: Verify as-built IVS against design plan (Digital sensors)	Once, following IVS construction	Small ISO seed buried at 15cm medium ISO seed buried at 30cm	RCA/CA; Make necessary changes to seeded items and re-verify	Pass
Initial Instrument Function Test (PDM8®)	Once following assembly	PDM8®: All IVS seed items detected with response greater than target selection threshold	RCA/CA: Make necessary adjustments, and re-verify	Pass
Initial Instrument Function Test (Analog)	Once upon arrival at the project site	Audible response consistent with expected change in tone in presence of standard object	RCA/CA: Make necessary adjustments, and re-verify	Pass
Initial detection survey positioning accuracy (IVS) (Digital)	Once prior to start of data acquisition	Derived positions of IVS target(s) are within 25cm of the ground truth locations	RCA/CA: Make necessary adjustments, and re-verify	Pass
Initial detection survey Check for interference surrounding seed response (IVS) (All sensors)	Once prior to start of data acquisition	All seeds placed in locations that are free of detected anomalies within a radius of ≥1.5m	RCA/CA; and re-verify MQO	Pass
Preliminary Characterization (To delineate HD and LD areas)				
Ongoing instrument function test (DGM)	Beginning and end of each day and each time instrument is turned on	PDM8®: All IVS seed items detected with response greater than target selection threshold	RCA/CA: Make necessary repairs and reverify	Pass
Ongoing instrument function test (Analog)	Beginning and end of each day and each time instrument is turned on	Audible response consistent with expected change in tone in presence of standard object	RCA/CA	Pass
Ongoing detection survey positioning precision (IVS) (Digital)	Beginning and end of each day	Derived positions of IVS target(s) or target over test item placed at known location within 10m of the ground truth location	RCA/CA	Pass
In-line measurement spacing (Digital)	Verified for each transect using UX-Land sample separation gx for fiducial, RTS, or RTK GPS positioned data	98% ≤ 0.25m between successive measurements; 100% ≤1.0m	RCA/CA Coverage gaps are filled or adequately explained	Pass
Coverage – Transect mapping (All sensors)	Verified with target radius using VSP 'Post-survey probability of traversal' tool	Probability of traversal is 100% (excluding site-specific access limitations, e.g., obstacles, unsafe terrain, ROE refusal)	RCA/CA: Coverage gaps are filled or adequately explained	Pass
Geodetic Equipment Function Test	Daily (RTK GPS) Each time equipment is moved (RTS)	Measured position of control point within 10cm of ground truth	RCA/CA; document questionable information in database	Pass
HD Area Characterization – Detection Survey				
Geodetic Accuracy (Confirm Valid Position)	Evaluated for each measurement with RTK GPS or RTS positioning	GPS status flag indicates RTK fix (RTK GPS) RTS passes Geodetic Function Test (RTS)	RCA/CA; document questionable information in database	Pass
Ongoing Instrument Function Test (DGM)	Beginning and end of each day and each time instrument is turned on	PDM8®: All IVS seed items detected with response greater than target selection threshold	RCA/CA: Make necessary repairs and re-verify	Pass
Ongoing detection survey positioning precision (IVS) (Digital)	Beginning and end of each day	Derived positions of IVS targets(s) or target over test item placed at known location within 0.25 m of the ground truth location.	RCA/CA	Pass
Ongoing Instrument Function Test (Analog)	Beginning and end of each day and each time instrument is turned on	Audible response consistent with expected change in tone in presence of standard object	RCA/CA: Make necessary repairs and re-verify	Pass
In-line measurement spacing (Digital, all detection phases)	Verified using UX-Land sample separation gx for fiducial, RTS, or RTK GPS positioned data.	98% ≤ 0.25m between successive measurements; 100% ≤1.0m	RCA/CA Coverage gaps are filled or adequately explained (e.g., unsafe terrain)	Pass

Measurement Quality Objective	Frequency	Acceptance Criteria	Failure Response/Corrective Action	Status Following Remedial Investigation
HD Area Characterization – Detection Survey (continued)				
Coverage (Digital using electronic positioning, all phases)	Verified using UX-Land cross-line spacing gx for fiducial, RTS, or RTK GPS positioned data.	≥90% at project design cross-track measurement spacing; 98% ≤ 0.6m, not including documented obstacles.	RCA/CA: Collect additional data to increase coverage percentage to meet acceptance criterion CA assumption: Gaps require fill-in lines to achieve re-quired coverage or collected data includes enough area to meet in-tended grid size	Pass
Coverage – Full coverage (Digital, using line and fiducial positioning, all phases)	Verified for each transect/grid	Visual inspection and photos of survey lanes/lines established using: tapes and rope lanes; OR tapes and marking paint; OR sub-meter accuracy track-plot (filtered) of each operator's pro-gress through assigned survey lanes	RCA/CA	Pass
Confirm adequate spacing between units (PDM8, all phases)	Evaluated at start of each day (or grid)	Minimum separation of 50m	RCA/CA: Recollect all coincident measurements	Pass
Detection survey performance (Digital)	Average one to three blind QC seed per in-strument per day. Seeds to be placed throughout expected detection depth range	For QC seeds: offset between selected anomaly location and seed item location is ≤ 55 cm for digital positioning systems or ≤ 50 cm + ½ line spacing for fiducially positioned data.	RCA/CA: Verify instrument is functioning correctly; if so, reduce threshold, or determine if seed is buried too deep. If instrument is not functioning correctly, recol-lect data.	Initially failed for one grid; grid re-collected and passed (see **Subsection 4.3.1.1** and RCA-01 [**Appendix D**])
HD Area Characterization – Intrusive Investigation				
Documenting recovered sources (All sensors)	Daily	All metallic debris collected is documented for the following at-tributes: Designation as UXO, MD, RRD or NMRD; UXO and MD described by type, weight, depth. Photos displaying all MD recov-ered (individual MD photos not necessary), and photos showing all surfaces of each MEC are recorded.	RCA/CA; document questionable information in data-base	Pass
Confirm anomaly resolution (DGM)	Evaluated for all intrusive results	Verification of anomaly footprint after excavation by secondary personnel, using original instrument (PDM8®), confirms anomaly is resolved below anomaly identification threshold AND Reported excavation findings match expectations	RCA/CA	Pass

Table 4.5 Measurement Quality Objectives for MC-Related Tasks and Status Following Remedial Investigation

Measurement Quality Objective	Frequency	Acceptance Criteria	Failure Response/Corrective Action	Status Following Remedial Investigation
Soil Sampling Equipment Decontamination (Visual inspection)	Between sampling locations	Soil sampling equipment decontaminated and stored in aluminum foil	Decontaminate item	Pass

5.0 Remedial Investigation Results

RI activities were conducted at the NDNODS Fort Tuthill Small Arms Range North MRS between 28 September 2020 and 16 November 2020. This chapter presents the results of the MEC and MC investigations at the MRS and describes the estimated extent of contamination.

5.1 MUNITIONS AND EXPLOSIVES OF CONCERN CHARACTERIZATION RESULTS

As described in **Chapter 3**, MEC characterization at the NDNODS Fort Tuthill Small Arms Range North MRS included conducting DGM transect and grid surveys (Phase I) followed by intrusive investigation of subsurface anomalies within grids (Phase II). This subchapter describes the results of the activities and investigations. Daily field reports are located in **Appendix F**.

5.1.1 MEC INVESTIGATION RESULTS

5.1.1.1 As described in **Subsection 3.4.3.2**, 8.25 miles of DGM transect surveys led to the differentiation between areas of low anomaly density considered to be relatively unaffected by concentrated munitions use and areas of high anomaly density potentially representing MEC-contaminated target areas. VSP analysis of the collected transect data calculated the probability of traversal of a theoretical target area in the areas surveyed to be 100% within accessible portions of the MRS. Based on the results of the transect survey the Project Team selected 7 grids (nominal 0.25-acre), totaling approximately 1.61 acres, to characterize the HD area(s) and approximately 1.15 acres (5 grids) to characterize the LD area(s).

5.1.1.2 Grid-based DGM data were collected to identify anomalies for intrusive investigation. The intrusive investigation was completed as described in the Final UFP-QAPP (Parsons 2020). The results of the intrusive investigation are presented in **Tables 5.1** and **5.2**. A total of 736 targets were intrusively investigated out of 1,295 detected anomalies in 7 HD grids at the NDNODS Fort Tuthill Small Arms Range North MRS. All 264 detected anomalies in 5 LD grids were intrusively investigated. A total of 1,559 targets were selected to be investigated; however, 559 of those targets were in grids with more than 150 targeted anomalies (Grids 1, 7, and 12), therefore a representative subset of DGM anomalies was intrusively investigated instead of 100% of DGM anomalies. ROE was not granted for the small sliver (< 1 acre) of Luke Air Force Base property in the southern portion of the MRS; therefore, it was not investigated.

5.1.1.3 The Preliminary CSM for the NDNODS Fort Tuthill Small Arms Range North MRS (Table 10.1 of the approved Final UFP-QAPP [Parsons, 2020]) contained a list of munitions known or suspected to be present at the MRS. No MEC was recovered or confirmed at the MRS during the RI fieldwork.

Table 5.1 Intrusive Results HD Grids

Type	Number Recovered	Percent (%)
MEC	0	0
MD	5	0.7%
OD (other debris)	681	92.5%
Other (seeds, duplicate anomaly, hot soil, etc.)	50	6.8%

Note: Anomaly resolution percentages presented for categories of intrusive findings represent actual results.

Table 5.2 Intrusive Results LD Grids

Type	Number Recovered	Percent (%)
MEC	0	0
MD	3	1.1%
OD (other debris)	192	72.8%
Other (seeds, duplicate anomaly, hot soil, etc.)	69	26.1%

Note: Anomaly resolution percentages presented for categories of intrusive findings represent actual results. OD = other debris.

5.1.1.4 MD recovery depths ranged from 2.5 to 25 cm bgs. The mean depth of recovery was 11 cm bgs for MD. 87.5% of the MD were recovered within 20 cm (8 inches) of the ground surface. These results are summarized in **Table 5.3**.

Table 5.3 Overview of Anomaly Recovery Depths

Item Type	Max. Depth (cm)	Mean Depth (cm)	% at 0-20 cm bgs
MEC	–	–	–
MD	25	11	87.5%
OD	120	7	95.9%

5.1.2 STATUS OF MUNITIONS AND EXPLOSIVES OF CONCERN DATA QUALITY OBJECTIVES

5.1.2.1 The overall project objective for MEC was to obtain data to sufficiently characterize the presence or absence as well as nature and extent of MEC contamination at the NDNODS Fort Tuthill Small Arms Range North MRS. To this end, specific DQOs were established. The MEC DQOs for this RI are described in the approved Final UFP-QAPP (Parsons, 2020). This section addresses the status of the MEC DQOs upon completion of the RI.

5.1.2.2 The MEC DQOs were achieved by completing the following actions:

- Conducted DGM surveys over transects spaced at approximately 150-ft intervals in the safety fan and 100-ft intervals in the small arms range using the PDM8®;
- Collected 1.61 acres of DGM data in HD grids and 1.15 acres of DGM data in LD grids;
- Intrusively investigated 1,000 targets in the RI grids;
- Confirmed by evaluation of the geophysical data that applicable MQOs were achieved for all related geophysical investigations; and
- Confirmed that applicable MQOs had been achieved for 1,000 (736 in HD grids/264 in LD grids) intrusive results.

5.1.2.3 Based on the summary above and the information presented elsewhere in this report, the data obtained during this RI are considered sufficient to characterize both the presence or absence and nature and extent of MEC contamination at the NDNODS Fort Tuthill Small Arms Range North MRS and the MEC DQOs for this RI are determined to have been achieved.

5.2 MUNITIONS CONSTITUENT CHARACTERIZATION RESULTS

The sampling strategy and method for the RI at the NDNODS Fort Tuthill Small Arms Range North is presented in **Subchapter 3.3**. The following sections describe the analytical results for the samples collected during these field tasks.

5.2.1 MUNITIONS CONSTITUENT INVESTIGATION RESULTS

5.2.1.1 As described in **Subchapter 3.5.2**, ISM samples were collected to complete the MC presence or absence and nature and extent characterization at the NDNODS Fort Tuthill Small Arms Range North MRS and to support potential risk assessment. Even though MC contamination is not expected in LUAs, four ISM SUs were placed coincident with each of the four DGM grids in which MD was found (grids 1, 2, 5, and 7) and analyzed for explosives at the discretion of the Project Team. Metals were not analyzed. Also, ten background ISM surface (0-6 inches bgs or 0-3 inches bgs where there was shallow rock/auger refusal) soil samples were collected to determine the naturally occurring concentrations of metals and confirm the absence of explosives outside the boundary of the MRS investigation area. The background samples were analyzed for MC metals (antimony, copper, lead, and zinc) and explosives.

5.2.1.2 The four incremental surface soil samples (FT-SS-0-6-01, FT-SS-0-6-02, FT-SS-0-6-05, and FT-SS-0-6-07) collected at 0-6 inches bgs were analyzed for explosives only as no MEC (or significant MD) was identified during the RI, no HUA was identified, and there was a significant amount of non-munitions related debris in these grids. Explosive compounds were not detected in any samples collected within the MRSto include the ten background samples. Based on these results, explosives were not retained for further evaluation and conduct of a risk assessment was not warranted.

5.2.2 STATUS OF MUNITIONS CONSTITUENT DATA QUALITY OBJECTIVES

5.2.2.1 In accordance with the Final UFP-QAPP (Parsons, 2020), the overall project objective for MC was to obtain data to sufficiently characterize the nature and extent of potential MC contamination at the Fort Tuthill Small Arms Range North MRS. The MC sampling strategy; however, was contingent upon identification of an HD area or areas (identified by significant subsurface anomaly presence) and its conversion to an HUA following intrusive confirmation of MEC (or significant MD presence). During the DGM surveys, several HD areas were identified within the MRS for evaluation as potential HUAs. Intrusive investigation ultimately did not support the HUA assertion due to the absence of MEC and only minimal MD presence. As such, no MC sampling was warranted. A teleconference meeting was held with the Project Team and, in the interest of thoroughness, soil samples were collected from the grids displaying any MD presence and analyzed for explosives only. Due to the high density of metallic cultural debris, no samples were collected for metals analyses.

The MC DQOs for this RI are described in detail in the approved Final UFP-QAPP (Parsons, 2020). This subchapter addresses the status of the MC DQOs upon completion of the RI at the Fort Tuthill Small Arms Range North MRS.

5.2.2.2 The MC DQOs were achieved by completing the following actions:

- Collected ISM soil sample for explosive analysis at *all* locations where MD were found during the RI. As noted above, no HUAs were identified during this RI within the MRS. Therefore, no sampling was required to meet the DQO. The soil samples collected for explosives analyses were collected per Project Team decision.
- Confirmed through data validation that applicable MQOs for sampling and analysis had been achieved.

5.2.2.3 Based on the summary above and the information presented elsewhere in this report, the data obtained during this RI are considered sufficient to confirm the absence of MC contamination within the Fort Tuthill Small Arms Range North MRS and the MC DQOs for this RI are determined to have been achieved.

5.3 EXTENT OF MUNITIONS AND EXPLOSIVES OF CONCERN AND MUNITIONS CONSTITUENT CONTAMINATION

5.3.1 EXTENT OF MUNITIONS AND EXPLOSIVES OF CONCERN CONTAMINATION

5.3.1.1 As described in **Subchapters 3.4.3** and **5.1.1**, approximately half of the 100-acre investigation area of the MRS was assumed to be a HD area and half was assumed to be LD areas. No MEC items were recovered

during the RI. MD was recovered from 2 grids (Grid 1 and Grid 7) within the HD area and 2 grids (Grid 2 and Grid 5) within the LD area.

5.3.1.2 Only 8 investigated locations had MD. MD was recovered to a maximum depth of approximately 25 cm bgs (~10 inches). The balance of the MD recovered from all depths was significantly less than 25 cm bgs with 87.5 percent recovered at less than 20 cm bgs (~8 inches). These results suggest that any potential MEC would likely be present on the surface or at very shallow depths throughout the MRS (most dependent on location and associated soil layer profile) and thus readily accessible for exposure as a result of most potential future land uses. The depth estimates are supported by the reported geologic conditions at the MRS, which are characterized primarily by Gravelly-Sand-Silt/Gravelly-Sand-Clay soil. It is not expected that munitions would reside below the gravel layer.

5.3.1.3 As discussed in **Section 3.4.2**, a target selection threshold of ten times site-specific background was used for the PDM8® data collected during the RI to ensure the maximum possible detection relative to the noise floor. Although extensive testing of PDM8® expected response has not been performed for varying munition types, it has been performed for standard small and medium ISOs, including real world testing against the seed items that were successfully detected during PDM8® complete coverage surveys

5.3.2 EXTENT OF MUNITIONS CONSTITUENT CONTAMINATION

As described in **Subchapter 5.2**, MC contamination was not identified within the MRS.

6.0 Contaminant Fate and Transport

Understanding the fate of the various MEC and MC contaminants present in or released to the environment is important to evaluate the potential hazards or risk posed by those contaminants to human health and the environment. For example, MEC may be present on the ground surface or be buried in the subsurface; however, it is possible for natural processes to result in the movement, relocation, or unearthing of the MEC, thereby increasing the chance of its subsequent exposure to human receptors. Furthermore, MC may remain inside intact munitions or may have been released to the environment during training activities. The following paragraphs discuss potential migration processes for and the potential migration routes of MEC and MC at the NDNODS Fort Tuthill Small Arms Range North MRS.

6.1 FATE AND TRANSPORT PROCESSES FOR MUNITIONS AND EXPLOSIVES OF CONCERN

The two primary natural processes that can result in the migration or exposure of MEC at an MRS are erosion and frost heave. Frost heave, which is a consideration in the mountains of Arizona, is the result of pressure created from the combination of freezing temperatures and soil defrosting. The fluctuating freezing and thawing conditions heave, or lift, the soil and along with imbedded objects such as stones and subsurface munitions. Natural erosion over time of soil by the wind or by water (precipitation runoff) can result in the exposure of buried MEC by the removal of the overlying soil. In some cases, if soil is unstable and the erosive force is sufficient to act on the sizes of munitions present, this process can also result in the movement of MEC from its original position to another location (typically somewhere downgradient of the wash).

6.2 FATE AND TRANSPORT FOR MUNITIONS CONSTITUENTS

6.2.1 Contaminant release and migration is evaluated for potential MC contamination, if present, because of the risk posed to receptors from exposure to contaminated media and the migration of chemicals through environmental media. The presence of MEC may result in a release of MC to a site, and migration of MC may occur because of releases by normal detonation, low-order detonations, demolition, or where deterioration of the MEC item exposes MC to climate. MC may include the filler, secondary explosives, propellants of the munitions, or components of the munition's cases.

6.2.2 If a release of MC is documented, the fate and transport of MC contaminants present in or released to the environment must be evaluated to support the overall evaluation of human health and/or ecological risks. As described in Section 5.2.1, no MC were detected in surface soil. For this reason, the fate and transport of MC was not evaluated for the NDNODS Fort Tuthill Small Arms Range North MRS.

7.0 Baseline Risk Assessment

7.1 INTRODUCTION

7.1.1 The purpose of a baseline risk assessment is to evaluate the potential current and future adverse health effects resulting from hazards or hazardous substances released at an MRS. The risk assessment evaluates the magnitude of the potential baseline hazard/risk at the MRS and identifies the sources of the greatest risk. The baseline risk does not take into account actions to control or mitigate releases. Results of the risk assessments are used to justify no further action or to aid in the development, evaluation, and selection of appropriate response alternatives.

7.1.2 Risk assessments are MRS-specific evaluations, which consider current and future land use and activities, and may vary in detail and extent to which qualitative and quantitative inputs are used. Generally, risk assessments follow a phased approach, starting with generic assumptions, moving toward a more complex MRS-specific evaluation as necessary. The complexity of the risk assessment depends on the particular circumstances of the MRS.

7.2 MUNITIONS AND EXPLOSIVES OF CONCERN HAZARD ASSESSMENT

7.2.1 MEC Risk Management Methodology (RMM) was applied to the MRS (discussed below), in accordance with the interim guidance document *Trial Period for Risk Management Methodology at Formerly Used Defense Sites Military Munitions Response Program Projects* (U.S. Department of the Army, 2020). This RMM involves the use of four matrices to define acceptable and unacceptable risk from MEC hazards based on an evaluation of site conditions related to the likelihood of an encounter, the severity of incident, and the sensitivity of interaction based on expected land use activities. The existing (i.e., baseline) conditions at the Fort Tuthill Small Arms Range North MRS using the risk matrices are presented in **Appendix G** and discussed below.

7.2.2 A qualitative risk assessment for MEC is based on the likelihood of a receptor encountering MEC, the likelihood of an unintentional detonation for a given encounter, and the severity of an unintentional detonation. The Risk Management Methodology uses four matrices to determine the baseline MEC risk. The four matrices include:

- **Matrix 1: The Likelihood of Encounter**. This matrix relates the site characterization data for amount of MEC potentially present (data from RI and previous investigations) to site use (based on CSM), to determine the likelihood of encountering MEC.
- **Matrix 2: The Severity of an Incident**. This matrix assesses the outcome of Matrix 1 as related to the severity of an unintentional detonation.
- **Matrix 3: The Likelihood of Detonation**. This matrix relates the sensitivity of the MEC to the likelihood for energy to be imparted on an item during an encounter by specific land users, as defined by the CSM.
- **Matrix 4: Acceptable and Unacceptable Site Conditions**. Matrix 4 combines the results of the previous matrices to differentiate between “acceptable” and “unacceptable” site conditions.

7.2.1.3 The RMM was applied separately to two identified LUAs. One LUA was designated as a 25-acre “focused” area comprised of the SAR berm, the surrounding area to include the prior munitions findings (2.36-inch bazooka rockets) locations, RI MD finding locations, and a buffer. This area includes the areas designated by the Park for future development and increased recreational use. The second LUA area consists of the balance of the MRS (75-acres). A separate set of RMM matrices were created for each of the two areas. The RMM was not applied to any HUAs, as no HUAs were identified during the RI. The RMM was also not applied to any NEU areas as also none were identified and they are presumed to have no unacceptable risk. Based on the RI data, the potential exists for receptors to be exposed to unacceptable explosive hazards at both the LUAs of the NDNODS Fort Tuthill Small Arms Range North MRS. The baseline risk assessment for the LUAs is summarized in **Table 7.1** and presented in **Appendix G**.

Table 7.1 Baseline Risk Assessment, Fort Tuthill Small Arms Range North MRS

Focused Area	Remainder of MRS

Matrix 1: Likelihood of Encounter

Likelihood of Encounter (*Amount of MEC versus Access Conditions*)		Access Conditions (frequency of use)			
		Regular	Often	Intermittent	Rare
Amount of MEC	Category I (Most)	Frequent	Frequent	Likely	Occasional
	Category II	Frequent	Likely	Occasional	Seldom
	Category III	Likely	Occasional	Seldom	Unlikely
	Category IV	Occasional	Seldom	Unlikely	Unlikely
	Category V	Seldom	Seldom	Unlikely	Unlikely
	Category VI (Least)	Unlikely	Unlikely	Unlikely	Unlikely

Matrix 2: Severity of Incident

Severity of Explosive Incident (*Severity vs. Likelihood of Encounter*)		Likelihood of Encounter (from Matrix 1)				
		Frequent	Likely	Occasional	Seldom	Unlikely
Severity	Catastrophic/Critical	A	A	B	B	D
	Modest	B	B	B	C	D
	Minor	B	C	C	C	D
	Improbable	D	D	D	D	D

Matrix 3: Likelihood of Detonation

Likelihood of Detonation (*Sensitivity vs. Likelihood to Impart Energy*)		Likelihood to Impart Energy on an Item			
		High	Modest		Inconsequential
Sensitivity	High	1	1	1	3
	Moderate	1	2		3
	Low	1	3		3
	Not Sensitive	2	3		3

Matrix 4: Acceptable and Unacceptable Site Conditions

Acceptable and Unacceptable Site Conditions		Result from Matrix 2			
		A	B	C	D
Result from Matrix 3	1	Unacceptable	Unacceptable	Unacceptable	Acceptable
	2	Unacceptable	Unacceptable	Acceptable	Acceptable
	3	Unacceptable	Acceptable	Acceptable	Acceptable

7.2.1.4 In accordance with the risk methodology, where unacceptable risks are present, further munitions response is recommended; where an acceptable risk is present, no further munitions response related action is recommended. This risk assessment determination for the RI along with stakeholder inputs will be used for development of remedial alternatives in a FS. The Risk Management Methodology evaluations in **Appendix G** provide the baseline for the assessment of response alternatives for the MEC contaminated portions of the MRS in a FS.

7.3 MUNITIONS CONSTITUENT RISK ASSESSMENT

7.3.0.1 The purpose of the MC risk assessment is to determine the potential risk to human health and ecological receptors associated with exposure to MC at the NDNODS Fort Tuthill Small Arms Range North MRS. An MC risk assessment is a scientific procedure used to estimate the potential for current and future potential adverse effects on human health and the environment from exposure to MC present in environmental media due to exposure to MC associated with site activities.

7.3.0.2 The CSM for the NDNODS Fort Tuthill Small Arms Range North MRS discussed in **Section 2.6** and presented in **Table 2.2** was updated based on the analytical results from the surface soil samples taken during the RI. Pathway completeness is based on the presence of a release of MC to an environmental medium resulting in a potential for exposure of human health and ecological receptors. Source to receptor exposure pathways are summarized and updated in the revised CSM discussed in **Section 5.4**.

7.3.0.3 Based upon the analytical results from the four surface soil samples discussed in **Section 5.2** and presented in the revised CSM (**Subchapter 5.4**), the exposure pathways are considered incomplete and no further evaluation in a risk assessment was necessary.

8.0 Summary of Remedial Investigation Results & Munitions Response Site Prioritization Protocol

8.1 REMEDIAL INVESTIGATION RESULTS SUMMARY

The purpose of this RI is to define the horizontal and vertical extent of MEC and MC contamination to evaluate the potential for unacceptable risks within the NDNODS Fort Tuthill Small Arms Range North MRS. **Sections 8.1.1** and **8.1.2** below summarize the nature and extent of MEC and MC concerns.

8.1.1 MUNITIONS AND EXPLOSIVES OF CONCERN

8.1.1.1 NATURE AND EXTENT OF CONTAMINATION

8.1.1.1.1 DGM followed by intrusive investigation of anomalies was completed where ROE was obtained. ROE was not obtained for a small sliver (< 1 acre) parcel on the southeastern perimeter of the MRS, owned by Luke Air Force Base Recreational Center, utilized as a recreational vehicle (RV) parking area. The Project Team determined the parcel was inconsequential to the conduct of the RI based on the small size and location with regard to potential range configurations and features.

8.1.1.1.2 Initially in Phase I, transects were geophysically surveyed (DGM) to identify the anomaly density distribution across the MRS and extrapolate this data to develop a composite anomaly density "heat" map. The VSP-modeled anomaly density results were then used to differentiate between HD (suspect HUA) and LD areas based on contours applied along threshold values. The boundaries of the HD and LD areas were further refined based on subsequent geophysical and intrusive grid data. The combined anomaly density information and intrusive results (Phase II) was then used to assess the presence of HUAs, LUAs, and NEU within the MRS. Based on the absence of MEC and lack of significant MD findings during the intrusive investigation portion of the fieldwork, the entire MRS was designated as an LUA. However, since historically one MEC item consisting of a 2.36-inch bazooka rocket was identified in 2017 and one practice rocket was reported in 2000, an unacceptable explosives risks remains in the LUA based on current and reasonably anticipated future use.

8.1.1.2 RISK ASSESSMENT

MEC Risk Management Methodology (RMM) was applied to the MRS. Based on the reports of two historical MEC finds and the current land use and accessibility of the MRS, there is an unacceptable risk for human receptors to be exposed to explosive hazards within the NDNODS Fort Tuthill Small Arms Range North MRS.

8.1.2 MUNITIONS CONSTITUENTS

8.1.2.1 NATURE AND EXTENT OF CONTAMINATION

In addition to ten background samples, biased surface soil samples were collected from within the four grids where MD was recovered during the RI. Although the MC sampling criteria were not met during this RI due to the absence of one or more identifiable HUAs, soil samples were collected and analyzed for explosives to provide additional confirmation of absence of MC contamination within the MRS. No explosive constituents were detected in surface soil, thus the nature and extent of MC contamination is defined as not present.

8.1.2.2 RISK ASSESSMENT

Based on the results of the RI sampling, no MC contamination was identified within the MRS. No HUAs were identified, however MC samples (for explosives) were collected from within the LUA at the four grids where MD was recovered.

8.2 MUNITIONS RESPONSE SITE PRIORITIZATION PROTOCOL

8.2.1 INTRODUCTION

8.2.1.1 This section discusses application of the MRSPP for the NDNODS Fort Tuthill Small Arms Range North MRS (AZHQ-005-R-01). The MRSPP was applied in accordance with 32 Code of Federal Regulations (CFR) Part 179 and the guidance provided in the DoD MRSPP Primer (DoD, 2007). The MRSPP worksheet tables for the MRSs are included in **Appendix H**. In 2005, DoD published the MRSPP as a Federal Rule (32 CFR Part 179) to assign a relative risk priority to each defense site in the MMRP Inventory for response activities. These response activities are based on the overall conditions at the MRS, taking into consideration various factors related to explosive safety and environmental hazards. The application of the MRSPP applies to all locations:

- That are or were owned, leased to, or otherwise possessed or used by DoD
- That are known to or are suspected of containing MEC or MC
- That are included in the MMRP Inventory

8.2.1.2 In assigning a relative priority for response activities, DoD generally considers MRSs posing the greatest hazard as being the highest priority. In the MMRP, the MRSPP priority will be one factor in determining the sequence in which munitions response actions are funded. The following sections are a brief summary of the modules of the MRSPP and the results of the evaluations for the NDNODS Fort Tuthill Small Arms Range North MRS.

8.2.2 EXPLOSIVE HAZARD EVALUATION MODULE

8.2.2.1 The Explosive Hazard Evaluation (EHE) Module assesses the explosive hazards of a MRS based on the known or suspected presence of an explosive hazard, including small arms ranges. The EHE Module is composed of three factors, each of which has two to four data elements that are intended to assess the specific conditions at an MRS. Based on site-specific information, each data element is assigned a numeric score, and the sum of these values is the EHE Module score and is used to determine the corresponding EHE Module rating. The data elements are as follows:

- **Explosive Hazard Factor.** Has the data elements Munitions Type and Source of Hazard and constitutes 40 percent of the EHE Module score.
- **Accessibility Factor.** Has the data elements Location of Munitions, Ease of Access, and Status of Property and constitutes 40 percent of the EHE Module score.
- **Receptor Factor.** Has the data elements Population Density, Population Near Hazard, Types of Activities/Structures, and Ecological and/or Cultural Resources and constitutes 20 percent of the EHE Module score.

8.2.2.2 The NDNODS Fort Tuthill Small Arms Range North MRS received the EHE Module rating of B. This module rating was based on the reported historical discoveries of two 2.36-inch bazooka rockets (one practice and one HE) from within the MRS and 57mm HE recoilless rifle and 60mm HE mortar MD identified in the MRS subsurface during the RI intrusive investigation. The MRS is owned and operated by Coconino County as Fort Tuthill County Park and is open to the public. Park areas within the investigation area include the multiple use trails, Flagstaff Extreme Adventure Course (obstacles and zipline course), Fort Tuthill Campground, Bike Park, Equestrian Cross-County Jump Course, and Flagstaff Snow Park (snow tubing park). The EHE Module rating is preliminary and is awaiting stakeholder input. The EHE Module worksheet tables are presented in **Appendix H** and summarized in **Section 8.2.5**.

8.2.3 CHEMICAL WARFARE MATERIAL HAZARD EVALUATION MODULE

8.2.3.1 The Chemical Warfare Materiel (CWM) Hazard Evaluation (CHE) Module provides an evaluation of the chemical hazards associated with the physiological effects of CWM. The CHE Module is used only when CWM in the form of MEC or MC are known or suspected of being present at an MRS. Like the EHE Module, the CHE

Module has three factors, each of which has two to four data elements that are intended to assess the conditions at an MRS. These factors are as follows:

- **CWM Hazard Factor.** Has the data elements CWM Configuration and Sources of CWM and constitutes 40 percent of the CHE score.
- **Accessibility Factor.** Focuses on the potential for receptors to encounter the CWM known or suspected to be present on an MRS. This factor consists of the data elements "Location of CWM", "Ease of Access", and "Status of Property", and constitutes 40 percent of the CHE score.
- **Receptor Factor.** Focuses on the human and ecological populations that may be impacted by the presence of CWM. It has the data elements Population Density, Population Near Hazard, Types of Activities/Structures, and Ecological and/or Cultural Resources and constitutes 20 percent of the CHE score.

8.2.3.2 Similar to the EHE Module, each data element is assigned a numeric value, and the sum of these values is the CHE Module score, which is used to determine the corresponding CHE Module rating. If CWM is not known or suspected, then the CHE Module rating is No Known or Suspected CWM Hazard.

8.2.3.3 The NDNODS Fort Tuthill Small Arms Range North MRS received the Alternative CHE Module rating of "No Known or Suspected CWM Hazard". This was due to the fact that no historical or physical evidence was found during SI or RI activities that indicated CWM is present or was ever used at the MRS. The worksheet tables are presented in **Appendix H** and summarized in **Section 8.2.5**.

8.2.4 HEALTH HAZARD EVALUATION MODULE

8.2.4.1 The Health Hazard Evaluation (HHE) Module provides a consistent DoD-wide approach for evaluating the relative risk to human health and the environment posed by contaminants (i.e., MC) present at an MRS. The module has three factors that are as follows:

- **Contamination Hazard Factor (CHF).** Evaluates potential risk posed by contaminants and contributes a value of High (H), Medium (M), or Low (L) based on Significant, Moderate, or Minimal contaminants present, respectively.
- **Migration Pathway Factor (MPF).** Assesses the potential for MC or incidental contaminants to migrate from an MRS and contributes a value of H, M, or L based on "Evident", "Potential", or "Confined" pathways, respectively.
- **Receptor Factor (RF).** Evaluates the presence of receptors that may be exposed and contributes a value of H, M, or L based on "Identified", "Potential", or "Limited" receptors, respectively.

8.2.4.2 The HHE builds on the DoD Relative Risk Site Evaluation framework that is used in the Installation Restoration Program. The CHF, MPF, and RF are based on quantitative evaluation of MC and/or CERCLA hazardous substances and a qualitative evaluation of pathways and human and ecological receptors in surface soil, groundwater, surface water, and sediment. The HHE does not address subsurface soils. In addition, the HHE does not consider air as a pathway, because the risk through this medium from DoD MMRP sites with soil contamination is generally minimal.

8.2.4.3 The H, M, and L levels for the CHF, MPF, and RF are combined in a matrix to obtain composite three-letter combination levels that integrate considerations of all three factors. The three-letter combination levels are organized by frequency and the combination of the frequencies results in the HHE Module rating.

8.2.4.4 The NDNODS Fort Tuthill Small Arms Range North MRS received the alternative HHE Module Rating of "No known or Suspected Contamination Hazard". The HHE Module rating is based on the SI lead levels detected previously below levels of concern and the non-detect concentrations of explosive constituents in soil during the RI. The HHE Module worksheet tables are presented in **Appendix H** and summarized in **Section 8.2.5**.

8.2.5 MUNITIONS RESPONSE SITE PRIORITIZATION PROTOCOL SCORES

8.2.5.1 In accordance with the DoD MRSPP Primer (DoD, 2007), the MRS is assigned an MRSPP Priority ranging from 1 to 8. Priority 1 indicates the highest potential hazard and Priority 8 indicates the lowest potential

hazard. Only a site with a potential Chemical Warfare Hazard can receive a Priority of 1. The priority is determined by selecting the highest rating from among the EHE, CHE, and HHE Modules. For example, if the EHE rating is 2, the CHE rating is 5, and the HHE rating is 4, the priority assigned would be 2. An alternative rating may be selected for the MRS if it meets the criteria. The priority will be used to determine the future funding sequence of the MRS for further munitions response action.

8.2.5.2 The overall MRSPP priority for the NDNODS Fort Tuthill Small Arms Range North MRS (AZHQ-005-R-01) is assigned a 3. The CHE and HHE module ratings were each "No Known or Suspected Hazard", while the EHE rating was B. A summary of the MRSPP scores for each module is provided in **Table 8.1**.

Table 8.1 Munitions Response Site Prioritization Protocol Summary

MRSPP Module	Factors			Module Total	Module Rating
	Hazard	Accessibility/ Migration	Receptor		
EHE Module	30+10	25+10+5	5+1+5+5+0	90	B
CHE Module	0	0	0	0	NKSH
HHE Module	NA	NA	NA	NA	NKSH

Notes:

3 MRSPP Priority

NKSH = No Known or Suspected Hazard

8.3 CONCLUSIONS

This section provides the RI conclusions and recommendations for MEC and MC. The results of this RI and the assessment of MEC hazards indicate that the MEC contamination identified at the NDNODS Fort Tuthill Small Arms Range North MRS poses an unacceptable risk from explosive hazards to current and future receptors. There are no unacceptable hazards to human health or ecological receptors resulting from exposure to MC in soil.

8.3.1 RECOMMENDATIONS FOR FS

8.3.1.1 The presence of MEC hazards negates the potential acceptability of the "no-action" response. It is recommended that a risk management decision to address unacceptable explosive risks from MEC be carried forward to the FS phase to develop and evaluate appropriate remedial alternatives for presentation to decision-makers and to support remedy selection for explosive hazards. Alternatives have been developed that protect human health by eliminating, reducing, and/or managing explosive risks posed through each exposure pathway.

8.3.1.2 The collected MEC data and associated characterization described in this RI report are considered sufficient to fully characterize the 100-acre NDNODS Fort Tuthill Small Arms Range North MRS, to identify and evaluate any associated potential MEC hazards, and to fully support the recommended FS. The next step after an FS would be to prepare a Proposed Plan to convey this finding to the public, followed by a Decision Document to formally memorialize the selected remedy at this MRS.

9.0 Identification and Screening of Remedial Technologies

This chapter identifies the remedial technologies available to address the MEC risk at the NDNODS Fort Tuthill Small Arms Range North MRS and screens these technologies to establish which are technically implementable at the site. The process used for developing and screening technologies includes establishing RAO and developing general response objectives that describe areas or volumes of media to which response actions may be applied and that can be used for screening the technologies. Once these steps are completed, potential contamination treatment and removal technologies are identified and assessed for technical implementability. The identification of treatment and removal technologies includes consideration of the types of response actions selected for other sites with similar contamination. The following sections describe the RAO for the NDNODS Fort Tuthill Small Arms Range North MRS, outline the general response actions to be considered, and summarize the available remedial technologies for MEC.

9.1 REMEDIAL ACTION OBJECTIVES

9.1.1 INTRODUCTION

9.1.1.1 RAOs are developed to address the goals of reducing risk to ensure protection of human health, safety, and the environment (U.S Environmental Protection Agency [USEPA], 1988). RAOs are intended to be as specific as possible without limiting the range of alternatives that can be developed or to prescribe a particular alternative. They are identified for the hazardous substances in each specific medium to which receptors can become exposed (e.g., MEC in soil or lead in groundwater). Regulations often require RAOs achieve certain mandated criteria (e.g., drinking water maximum contaminant levels). They specify contaminant(s) and media of concern; exposure route(s) and receptor(s); and remediation goal(s) for each exposure route. Regulations often require that RAOs achieve certain mandated criteria. RAOs specify:

- Explosive safety hazards and chemicals of concern;
- ARARs;
- Exposure pathways;
- Receptors and potential receptors; and
- Preliminary remediation goals (PRG) for each exposure pathway that was identified during the RI.

9.1.1.2 The typical method for developing RAOs at hazardous waste sites involves considering the nature and extent of contamination, current and future receptors, the exposure pathways, and current and future land use. Based on this information, the appropriate cleanup levels can be established. Site-specific RAOs can be found in Table 9.2.

9.1.2 EXPLOSIVE SAFETY HAZARDS AND CONTAMINANTS OF CONCERN

9.1.2.1 EXPLOSIVE SAFETY HAZARDS

The results of the RI, previous field investigations, and the known prior munitions use were used to evaluate the explosive safety hazards at the NDNODS Fort Tuthill Small Arms Range North MRS. The results of the RMM assessment for the NDNODS Fort Tuthill Small Arms Range North MRS indicate the overall risk from explosive hazards is unacceptable for the entire MRS under current and future conditions.

9.1.2.2 CHEMICALS OF CONCERN

No HUAs were identified during the RI; therefore, the criteria for implementation of MC sampling was not met. However, ISM soil samples were collected from each of the four grids displaying MD contamination during the RI intrusive investigation at the discretion of the Project Team. These samples were analyzed for explosives only.

No detectable explosives concentrations were detected. Given both the absence of an HUA within the MRS and no explosives contamination in the discretionary samples, an MC exposure pathway is not present (no MC contamination) and a risk assessment was not conducted.

9.1.3 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND "TO BE CONSIDERED" INFORMATION

9.1.3.1 Under Section 121 (d)(2)(A) of CERCLA, remedial actions must meet a level and standard of control that attain standards, requirements, limitations, or criteria that are "applicable or relevant and appropriate" under the circumstances of the release. These requirements are derived from federal and state laws and are known as ARARs. Federal, state, or local permits are not necessary for removal or remedial actions implemented under a CERCLA remedial action, but ARARs must be met.

9.1.3.2 In addition to legally binding laws and regulations, many federal and state environmental public health programs also develop criteria, advisories, guidance, and proposed standards that are not legally binding, but which may provide useful information or recommended procedures. These TBC requirements are not promulgated, and thus, are not potential ARARs. State requirements identified in a timely manner that are more stringent than corresponding federal requirements may be applicable or relevant and appropriate. The USEPA classifies ARARs as chemical-, action-, and location-specific to provide guidance for identifying and complying with ARARs (USEPA, 1988). All ARARs must meet the following criteria:

- Are limited to promulgated requirements,
- Are environmental or facility siting laws,
- Are substantive requirements, and
- Pertain to the circumstances at the MRS.

9.1.3.3 ARARs are grouped into the following three categories:

- **Chemical-Specific ARARs:** These are usually health- or risk-based numerical values or methodologies. Applying these numerical values establishes the acceptable amount or concentration of a chemical that may exist in a medium or that may be discharged to the environment.
- **Action-Specific ARARs:** These are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous waste.
- **Location-Specific ARARs:** These include restrictions placed on the concentrations of hazardous substances or the conduct of activities solely because they occur in special locations.

9.1.3.4 Identification of potential ARARs was conducted as part of this RI/FS as presented in **Section 2.8** and **Table 2.3**. The ARARs were selected as applicable or relevant and appropriate to the MRS (as CERCLA applies to the MMRP) and will be evaluated for the proposed alternatives.

9.1.4 RECEPTORS AND POTENTIAL RECEPTORS

Human receptors are categorized by their ability to access a site combined with activities that potentially allow for contact (i.e., interaction) with MEC. Receptors at the NDNODS Fort Tuthill Small Arms Range North MRS include on-site workers (i.e., Fort Tuthill County Park workers), construction workers, and site visitors/recreational users (hikers, bikers, horseback riders, campers, archers). Ecological receptors are not likely, except in the rarest of circumstances, to act on MEC in a manner forcible enough to initiate an unintentional detonation. For this reason, MEC does not pose an appreciable threat to soil, biota, plants, or animals. Therefore, ecological receptors are not considered further in the development of the MEC-related RAOs.

9.1.5 EXPOSURE PATHWAYS

Based on the presence of MEC and the general level of site accessibility, the existence of complete MEC exposure pathways in soil is confirmed at the NDNODS Fort Tuthill Small Arms Range North MRS. A summary of the exposure pathway for receptors present is presented in **Table 9.1**.

Table 9.1 Summary of Exposure Pathways

Medium	Hazard	Receptors	Exposure Pathways
Soil	MEC on surface and in subsurface, down to 25 cm bgs	On-site workers (i.e., Fort Tuthill County Park workers), construction workers, and site visitors/recreational users (hikers, bikers, horseback riders, campers, archers)	*Surface*: Presence at site; direct contact *Subsurface*: Possible intrusive activities to 60 cm bgs or more by site workers

9.1.6 PRELIMINARY REMEDIATION GOALS

9.1.6.1 PRGs are both site- and contaminant-specific and define the conditions considered by stakeholders to be protective of human health and the environment. PRGs provide a design target for the analysis of and selection of remedial alternatives. For this reason, PRGs are screening tools rather than the final remediation target or cleanup level and they are designed to be conservative. As with the CSMs, PRGs may be reevaluated and refined throughout the RI/FS process as new information becomes available. The preliminary goal of the RI/FS for the NDNODS Fort Tuthill Small Arms Range North MRS was to determine the presence or absence as well as nature and extent of munitions contamination; and the ultimate goal for the MRS is to manage any risk from MEC that may be present.

9.1.6.2 Consequently, the preliminary remediation goal for MEC is based on limiting interaction between any residual MEC and any receptors accessing the MRS. Based on the project goals, the PRG for MEC is defined as "no unacceptable risks resulting from human exposure to MEC." This PRG will require remedial alternatives to minimize unintentional human exposure to surface or subsurface MEC and will be evaluated using the RMM, as described in the study paper titled, "*Decision Logic to Assess Risks Associated with Explosive Hazards, and to Develop (Remedial Action Objectives) RAOs for MRSs*" (USACE, 2017).

9.1.7 REMEDIAL ACTION OBJECTIVE

9.1.7.1 The RAO addresses the goals for reducing the MEC hazards to ensure protection of human health, safety, and the environment. Based on the known current conditions and the explosive safety hazards described in **Chapter 2**, a site-specific RAO was developed to address MEC (**Table 9.2**). This RAO is based on the format recommended in the study paper titled, "*Decision Logic to Assess Risks Associated with Explosive Hazards, and to Develop (Remedial Action Objectives) RAOs for MRSs*" (USACE, 2017).

9.1.7.2 There is no MC risk to human health and the environment in the MRS. Based on the results of the RI, the RAO developed for the MRS is as follows in Table 9.2:

Table 9.2 Remedial Action Objectives

Medium	Soil
Contaminant	MEC (UXO): Surface to depth based on RI intrusive data to be primarily less than 25cm (10 inches) below ground surface (bgs) in NDNODS Fort Tuthill Small Arms Range North MRS. Historically one MEC item was found during construction activities at unknown depth and one practice munition was identified at the surface. No MD was recovered on the surface during the RI. 100% of MD was recovered from 25cm or less bgs. The maximum depth of MD was 25cm (10 inches) bgs.

Receptors	On-site workers (i.e., Fort Tuthill County Park workers), construction workers, and site visitors/recreational users (hikers, bikers, horseback riders, campers, archers).
Exposure Pathways	Presence at site; direct contact (e.g., recreational users, on-site workers, etc.), possible intrusive activities extend through MEC depth (e.g., construction workers, on-site workers, etc.).
RAO	To reduce the risk due to presence of 2.36-inch bazooka rockets; 60mm HE mortars; and 57mm HE recoilless rifles within the NDNODS Fort Tuthill Small Arms Range North MRS on the surface and in the subsurface to the depth of contamination (depths up to 25 cm bgs) to address likelihood of exposure to on-site workers (i.e., Fort Tuthill County Park workers), construction workers, and site visitors/recreational users (hikers, bikers, horseback riders, campers, archers) via direct contact, through a source removal to 60 cm (24 inches) bgs or more, an implementation of land use controls, access restrictions, or a combination thereof, such that an acceptable condition (as defined by RMM Matrix 4) is achieved.

This RAO was used to evaluate the protectiveness of the remedial alternatives (**Chapters 10 and 11**). All remedial alternatives developed must achieve the selected RAO when implemented.

9.2 GENERAL RESPONSE ACTIONS

This section summarizes the General Response Actions (GRAs) that are relevant for munitions actions under the Technical Guidance for Military Munitions Response Actions, EM 200-1-15 (USACE, 2018). GRAs are those actions that will achieve the RAO and may include remedial actions for detection and removal/recovery of MEC and remedial actions for disposal (demolition) of MEC, land use restrictions such as LUCs, or combinations of these actions. Under CERCLA, evaluation of a "No Action" alternative is also required to provide a baseline for the other remedial technologies and alternatives. No action refers to a remedy where no active remediation or enforceable land use restrictions such as LUCs are implemented. The DERP manual (DoD, 2012) requires the DoD component to include at least three alternatives including No Action, an action to remediate to UU/UE, and an action to remediate to a protective condition that requires land use restrictions (i.e., LUCs or exposure controls). The following GRAs have been identified and are considered for the MRS:

- **LUCs** – LUCs are designed to prevent or limit exposure of receptors to explosive hazards from military munitions. LUCs can include physical, legal, educational, and administrative mechanisms used to mitigate the explosive hazards associated with the MEC present within the MRS. Note that ARNG is unable to implement an environmental convenant, deed restriction, or similar real estate encumbrance on land outside of DoD control. As such, institutional controls (ICs) (deed notices, permits, or restrictions on excavation) are not considered for the NDNODS Fort Tuthill Small Arms Range North MRS due to a lack of landowner support for such measures. Physical measures (engineering controls) such as fencing, barriers, or gates are not considered due to the current land use as a park. Educational controls and warning signs, at least as part of a larger remedial plan, are accepted and carried further.

- **MEC Detection/MEC Removal** – The GRA to accomplish physical removal of MEC requires various detection technologies to locate explosively hazardous items (e.g., MEC) in the environment. Detection is generally used in conjunction with removal and demolition to meet the RAO but can also be used to identify areas for LUCs. MEC detection technologies include surface detection, subsurface analog survey, and subsurface digital survey. Detection process options examined include instrument–aided surface sweep (for surface detection), analog magnetometers and electromagnetic detectors (for subsurface analog surveys), and digital magnetometers and electromagnetic instruments, and AGC sensors (for subsurface digital surveys). The GRA of MEC treatment and removal was focused only on in-situ excavation that requires manual excavation by UXO technicians.

- **MEC Treatment and Disposal** – The GRA for MEC treatment and disposal that was considered was only on-site treatment. Process options that were evaluated were BIP or consolidated detonation for destroying MEC found in place using donor explosives or moving MEC to a central disposal area and detonating with donor explosives, respectively. MD that is generated is then certified as MDAS and disposed offsite.

9.3 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

9.3.1 BACKGROUND

9.3.1.1 Pursuant to the Technical Guidance on for Military Munitions Response Actions (USACE, 2018), planning for a munitions removal action requires that a strategy be developed to efficiently and effectively meet project needs. This FS defines the goals of the strategy and RAO of the action as well as the means (i.e., processes and technologies) to accomplish the RAO. An initial list of remedial technologies was developed based on Version 4.0 of the Remediation Technologies Screening Matrix and Reference Guide produced by the Federal Remediation Technologies Roundtable (FRTR) (FRTR, 2007). The FRTR is a consortium of government agencies that have worked to build a more collaborative atmosphere among federal agencies involved in hazardous waste site remediation.

9.3.1.2 This section identifies the potentially applicable technologies for MEC in soil at the NDNODS Fort Tuthill Small Arms Range North MRS. Overviews of the various technologies can be found in **Section 9.3.2**. The remedial technologies were screened to eliminate those technologies that cannot be technically implemented at the site. Landowners may also permit or prohibit the use of the proposed remedial technologies on their property. This technology screening is distinct from the alternative screening that may be conducted later in this report once alternatives have been developed. The results of the screening evaluations are described in **Section 9.3.3** and summarized in **Table 9.3**.

9.3.2 POTENTIALLY APPLICABLE TECHNOLOGIES

9.3.2.1 LAND USE CONTROLS

9.3.2.1.1 The three types of LUCs defined by DERP include physical, legal, and administrative controls. The DERP Manual (DoD, 2012) gives the following descriptions of the LUCs types:

- Physical mechanisms encompass a variety of engineered remedies to contain or reduce contamination and physical barriers to limit access to property;
- Legal mechanisms include restrictive covenants, negative easements, equitable servitudes, and deed notices; and
- Administrative mechanisms include notices, adopted local land use plans and ordinances, construction permitting, or other land use management systems to ensure compliance with the use restrictions.

9.3.2.1.2 LUCs can be implemented either alone or in conjunction with other remedial actions. The administrative feasibility of implementing LUCs depends on site-specific circumstances, including whether a site is under the direct operational control of the DoD or was transferred to non-federal ownership, as well as on the ability, willingness, and commitment of local authorities to implement institutional controls. Inspections and monitoring are typically required to document the long-term effectiveness of institutional controls.

9.3.2.1.3 Physical mechanisms can prevent or limit uncontrolled access to the contaminated area. In the case of MEC, such restrictions prevent access to both surface and subsurface hazards by potential receptors. Physical mechanisms include the installation of fencing or some type of physical barrier over the surface of the affected area to reduce or eliminate the potential for receptor interaction with subsurface MEC. Fencing can be used in conjunction with administrative methods, such as signs, to enhance the awareness of site receptors regarding the potential hazards.

9.3.2.1.4 Legal mechanisms can limit contact with MEC by preventing or otherwise controlling the way receptors might be exposed. Use restrictions and regulatory controls dictate the type of development that will occur on a site and the methods in which that development occurs. For example, using a deed notice or restrictive covenant to designate the land use in an area as commercial/industrial only would prevent future residential or recreational land uses at the site. Other common activity restrictions for a contaminated area include total prohibitions on intrusive activities or implementing a “no parking” restriction.

9.3.2.1.5 Administrative mechanisms involve increasing potential receptors’ awareness of the hazards at a site. Available processes include installing signage and distributing educational materials. Placing signs around

a contaminated area can help to warn potential receptors of the associated hazards so they can choose to avoid them entirely by not entering the affected area or make them less likely to interact with potential hazards (e.g., suspicious items that might be MEC) if they do enter the area. Signs can also be used in conjunction with physical mechanisms, such as fencing. Similar to signs, educational materials warn potential receptors of the associated hazards so they can choose to avoid them entirely by not entering the affected area or make them less likely to interact with potential hazards.

9.3.2.2 MEC DETECTION TECHNOLOGIES

9.3.2.2.1 A number of effective technologies exist for detection of MEC, with some supported by subsets of systems for transport, positioning and navigation, and data processing and analysis. Detection and location technologies for MEC primarily depend on the ability of geophysical instruments to distinguish the physical characteristics of MEC from those of the surrounding environment. Information on the capabilities of existing technologies have been balanced against site-specific conditions throughout the MRS to screen out approaches that are not suitable. This section evaluates geophysical and positioning technologies for MEC detection using summary information for each method from the USACE Technical Guidance for Military Munitions Response Actions, Engineering Manual 200-1-15 (USACE, 2018).

9.3.2.2.2 Detection of MEC on the surface or in the subsurface can be accomplished using analog methods, digital methods, or Advanced Geophysical Classification (AGC) methods. However, according to the DoD-USEPA Joint UXO Management Principles, 'To the maximum extent practicable, the permanent record shall include sensor data that is digitally-recorded and geo-referenced". In the munitions response industry, analog methods refer to the use of handheld detector technologies operated by UXO technicians to identify anomalies (detect and count, detect and dig). Analog results cannot be digitally recorded and are generally not geo-referenced except for grid boundaries and MEC items recovered. Digital methods refer to DGM in which detector signals are digitally recorded with geo-referencing information to create a permanent record of the survey. AGC also provides digitally-recorded, geo-referenced data, while also allowing for the discrimination of TOI from non-TOI prior to intrusive investigation.

9.3.2.2.3 For AGC surveys, geophysicists use advanced electromagnetic induction sensors (such as MM2x2, MPV, APEX, and UltraTEM) to collect data which geophysicists can use to estimate the depth, size, wall thickness, and shape of each buried item. AGC is the process of using these data to make a more informed decision as to whether a buried metal item is a potentially hazardous munition or is metal clutter that can be left in the ground. AGC is used to focus a munitions response on excavating only those geophysical anomalies identified as potential munitions, resulting in a more efficient, more rigorous, better understood, and better documented munitions response *(Interstate Technology & Regulatory Council, Geophysical Classification for Munitions Response Technical Fact Sheet* [ITRC, October 2014]). AGC can be performed in one of three ways: 1) using the AGC equipment for mapping (dynamic mode) and for performing informed source selection to select anomalies, 2) using DGM or dynamic AGC for mapping and using cued AGC to determine if the anomalies are munitions (cued mode), 3) single pass mode where a dynamic AGC survey is collected with sufficient resolution to provide full anomaly classification to determine if the anomalies are munitions.

9.3.2.2.4 When MEC is located on the ground surface analog methods are appropriate, such as a detector-aided visual search by UXO technicians. When MEC is present in the subsurface DGM or AGC are most appropriate; however, analog methods may be necessary under certain conditions. The decision to use analog, DGM, AGC, or a combination of one or more is based on the project requirements, depth, and size of the suspected MEC, and the environmental characteristics present within the project area (i.e., topography, vegetation, and man-made features).

9.3.2.2.5 With regard to environmental characteristics, detector and positioning technologies and the specific equipment used have inherent advantages and disadvantages based on their design and operational characteristics. Detector technologies commonly used for terrestrial applications in the MR industry include magnetometry and EMI. Common positioning technologies/methods include GPS, relative coordinates (wheel counter mode /odometer, line and fiducial), and laser-based technologies such as RTS and SLAM. Positioning technologies are impacted primarily by obstacles (trees, structures), canopy (tree cover), and topography.

9.3.2.3 MEC REMOVAL TECHNOLOGIES

9.3.2.3.1 MEC removal is typically conducted using excavation to the depth of anomaly detection (i.e., the removal team continues digging until the anomaly source is located and removed) or excavation to a fixed removal depth. During excavation to a fixed depth, the removal team will stop digging at that depth whether or not the anomaly is resolved. This approach is typically used when the maximum potential intrusive depth for site receptors is established so removal will not need to proceed deeper than the fixed depth, or where the maximum potential depth of MEC was established.

9.3.2.3.2 Excavation technologies include manual and mechanical methods (e.g., mini-excavators, backhoes). Manual excavation is considered the industry standard for MEC recovery and can safely achieve good results. Mechanical excavation methods can be used if site conditions or the anticipated depth of MEC might make manual excavation challenging. Using mechanical excavators to remove MEC would necessitate the use of "up-armored" excavators to protect the operator in the event of an unintentional detonation and might require remote control equipment if large MEC items were present. Mechanical excavation methods can also be used in conjunction with mechanical sifting equipment to process quantities of soil containing large amounts of MEC or metal debris. Excavation and sifting is typically costly and results in large disturbances to the affected land.

9.3.2.4 MEC DISPOSAL TECHNOLOGIES

The disposal of MEC items recovered during removal operations includes the process option of using BIP procedures, or if the MEC items are deemed acceptable-to-move, performing consolidated demolition shots at the end of a project or on an as-needed basis.

9.3.3 TECHNOLOGY EVALUATION

9.3.3.1 LAND USE CONTROLS

Given the use of the majority of the NDNODS Fort Tuthill Small Arms Range North MRS as a county park, legal and physical mechanisms such as use restrictions and regulatory controls or physical barriers (i.e., fences, paved or gravel ground cover) would not likely be implementable since it would affect the current recreational use of the land. For these reasons, administrative mechanisms (i.e., warning signs and educational materials) are the only LUCs retained for consideration.

9.3.3.2 MEC DETECTION TECHNOLOGIES

Three detection technologies evaluated, analog geophysical surveys, DGM surveys, and DGM surveys with cued AGC, were retained for consideration. All three technologies are implementable, having been used at either the NDNODS Fort Tuthill Small Arms Range North MRS or similar sites. Additionally, with regard to performing analog geophysical surveys versus DGM/AGC, major parts of the terrain at the Fort Tuthill Small Arms Range North MRS are unlikely to require the use of analog instruments as the primary detection sensor, and digitally-recorded and geo-referenced geophysical data are preferred by DoD and USEPA, so analog surveys would only be implemented where DGM/AGC was not physically practical. The detection technology of dynamic AGC with limited cued AGC was evaluated but not retained for consideration. The terrain at the site prevents dynamic AGC from being implemented over major parts of the Fort Tuthill Small Arms Range North MRS.

9.3.3.3 MEC REMOVAL TECHNOLOGIES

Manual, mechanical, and mechanical excavation and sifting technologies were all evaluated in the screening process, all three methods are well-established and would be implementable at the MRS. However, it is anticipated that sifting would have a major impact on the current park lands at the MRS. For this reason, only manual and mechanical excavation methods were retained for consideration.

9.3.3.4 MEC DISPOSAL TECHNOLOGIES

The disposal of MEC items recovered during removal operations was also evaluated. This includes the process option of using BIP procedures, or if the MEC items are deemed acceptable-to-move, performing consolidated demolition shots at the end of a project or on an as-needed basis. These methods were both found to be implementable, and therefore retained for consideration

9.3.3.5 CONCLUSION

Screening level evaluation of remedial technologies were evaluated for implementability in **Table 9.3**. Relative cost information for technology screening represents the approximate technology cost only (implementation and operation), not the overall remedial cost to achieve a cleanup objective. All identified technologies retained for consideration are deemed physically and administratively implementable, and practical. The development and screening of alternatives is presented and evaluated in **Chapter 10**.

Table 9.3 Technology Screening and Evaluation

General Response Action	Remedial Technology	Process Options	Advantages	Disadvantages	Screening Evaluation	
					Implementable?	Retained for Consideration?
Land Use Controls	Physical Mechanisms	Security Fence – prevents or limits uncontrolled access to the contaminated area.	• Proven and routinely used • Prevents access to both surface and subsurface hazards • Accepted by regulators	• Negative impact on current land usage • Precludes current use	NO Landowner acceptance of fence installation and associated access restrictions highly unlikely as this would preclude current land use.	NO – screened out *Not readily implementable*
		Paved or Gravel Cover – installation of a physical barrier over the surface of the affected area using materials such as concrete, paving, or gravel.	• Prevents access to both surface and subsurface hazards	• Precludes current land use • Impractical for larger areas • Very invasive and greatly change the environmental quality of the site	NO Landowner acceptance of cover installation highly unlikely as this would preclude current land use.	NO – screened out *Not readily implementable*
		Earth Cover – installation of a physical barrier over the surface of the affected area using an earth material.	• Prevents access to both surface and subsurface hazards	• Precludes current land use • Very invasive and greatly change the environmental quality of the site	NO Landowner acceptance of cover installation highly unlikely as this would preclude current land use.	NO – screened out *Not readily implementable*
	Legal Mechanisms	Prohibit Specific Land Uses/Deed Notice – restrictions and regulatory controls dictating the type of development that will occur on a site and the methods in which that development occurs.	• Proven and routinely used • Limits or prevents contact with MEC • Accepted by regulators	• Negative impact on current land use • Landowners unlikely to accept limitations on the use of their land	NO Landowner acceptance of activity restrictions highly unlikely as this would negatively impact current land use.	NO – screened out *Not readily implementable*
	Administrative Mechanisms	Warning Signs – used to delineate the hazardous area clearly and act as a visual reminder. Placed along the perimeter of the MRS with extra signs placed at access points.	• Proven and routinely used • Increases awareness of MEC hazards • Accepted by regulators	• Only reaches those receiving the materials – land-owners, visitors at trail-heads, etc.	YES Readily implementable	**YES**
		Educational Materials – production and distribution of educational materials to inform receptors about the nature of the MEC present at the site.	• Proven and routinely used • Increases awareness of MEC hazards • Accepted by regulators	• Only reaches those receiving the materials – landowners, visitors at trailheads, etc.	YES Readily Implementable	**YES**
MEC Detection	Detection & Classification	Analog Geophysical Survey – UXO technicians operate handheld analog metal detectors over specified areas to identify potential surface and subsurface MEC.	• Proven and routinely used • May be used along ditches, in rough terrain, and closer to structures • Accepted by regulators	• Brush and understory vegetation may need clearing • Effectiveness dependent on the skill and experience of the instrument operator • Less effective than DGM. More MEC would remain in the ground. • No record of anomaly locations is available for review • Large number of potential digs produced	YES Readily Implementable; much of the terrain at each MRS is unlikely to require the use of analog instruments as the primary detection sensor, and digitally-recorded and geo-referenced geophysical data are preferred by DoD and USEPA (1).	**YES**
		DGM Survey – digital metal detectors are operated over specified areas while combined with location technology such as high-resolution global positioning system (GPS), Robotic Total Station, or fiducial lines on grids.	• Proven and routinely used • Proven at CSAR • Locations of anomalies are recorded	• Brush and understory vegetation may need clearing • Less effective near surface metal or structures including utilities	YES Readily Implementable; advantage over analog surveys is documented; audit trail of measurements and analysis provided.	**YES**

General Response Action	Remedial Technology	Process Options	Advantages	Disadvantages	Screening Evaluation	
					Implementable?	Retained for Consideration?
			• Anomaly selection can be tuned to site specific munitions • Accepted by regulators	• Difficult to use on slopes, ditches, and rough terrain •		
		DGM Survey/Advanced Geophysical Classification – DGM survey as above plus the use of an advanced sensor to evaluate anomalies identified in the initial (dynamic) DGM survey. Anomaly dig list is reduced by comparison of data with known responses of munitions.	• Proven and routinely used • Proven at CSAR • Anomaly selection can be tuned to site specific targets • Decreased number of digs • Accepted by regulators	• Brush and understory vegetation may need clearing • Less effective near surface metal or structures including utilities • Difficult to use on slopes, ditches, and rough terrain • Leaves munitions debris in the ground	YES Readily Implementable; advantage over analog surveys is documented; audit trail of measurements and analysis provided.	YES
MEC Removal	Excavation	Surface Clearance – anomalies are removed from surface by UXO technicians while maintaining exclusion zones (EZ) to protect the public and non-essential personnel.	• Proven and routinely used • Good safety record • Soil disturbance minimal • Accepted by regulators	• Requires specially trained personnel • Safety risk to workers due to potential unintentional detonations • EZ must be maintained, potentially required evacuations of non-essential personnel.	YES Readily Implementable; best for areas with no anticipated intrusive activities.	YES
		Manual Excavation – anomalies are dug by UXO technicians while maintaining exclusion zones to protect the public and non-essential personnel.	• Proven and routinely used • Good safety record • Soil disturbance limited to anomaly locations only • Accepted by regulators	• Requires specially trained personnel • Safety risk to workers due to potential unintentional detonations • EZ must be maintained, potentially requiring evacuations of non-essential personnel.	YES Readily Implementable; best for individual anomalies outside disposal features.	YES
		Mechanical Excavation – typically used to reach deeper anomaly sources. A small backhoe or excavator is used. Needed only if depths of clearance and MEC occurrence require it.	• Proven and routinely used • All MEC is removed to depth of investigation Good safety record • Accepted by regulators • Requires specially trained personnel	• Safety risk to workers due to potential unintentional detonations • May require armoring of the excavating equipment to protect the operator • EZ must be maintained, potentially requiring evacuations of non-essential personnel.	YES Readily Implementable; best for excavating disposal features and as needed to dig deeper anomalies.	YES
		Mechanical Excavation and Sifting – excavate all soil within a designated area and process it through a sifter to removal all MEC.	• Proven and routinely used • All MEC is removed to depth of investigation • Good safety record • Accepted by regulators	• Requires specially trained personnel • Safety risk to workers due to potential unintentional detonations • EZ must be maintained, potentially requiring evacuations of non-essential personnel. • All soil must be removed to depth of investigation • Greater environmental impact due to vegetation and soil removal • Not likely to be accepted by landowner	NO Landowner acceptance of bulk excavation and sifting highly unlikely as this would negatively impact current land use.	NO – screened out *Not readily implementable*

General Response Action	Remedial Technology	Process Options	Advantages	Disadvantages	Screening Evaluation	
					Implementable?	Retained for Consideration?
MEC Disposal	Demolition	BIP or Consolidated Shots – UXO technicians bring donor explosives to detonate the MEC, typically using engineering controls such as sandbags.	• Proven and routinely used • Hazard is eliminated quickly (in a few days) • Good safety record • Relatively inexpensive • Accepted by regulators	• Requires specially trained personnel • Safety risk to workers due to potential unintentional detonations • Blast may cause disturbance to the public • EZ must be maintained, potentially requiring evacuations of non-essential personnel.	YES Readily implementable, although proximity to inhabited structures may require evacuations. Public roads may need to be shut down temporarily.	YES

(1) USEPA Munitions Response Guidelines, USEPA Office of Solid Waste and Emergency Response (OSWER), OSWER Directive 9200.1-101, Federal Facilities Restoration and Reuse Office, Interim Final, July 27, 2010.

Shading indicates whether the process option passes or fails the screening criteria as follows:

PASSES	FAILS

10.0 Development of Remedial Alternatives

This chapter describes the development of remedial alternatives for the NDNODS Fort Tuthill Small Arms Range North MRS using the technology process options retained during the detailed screening process in **Chapter 9**. The remedial alternatives are developed to meet the RAOs for the MRS; therefore, alternatives have been developed by contaminant and exposure medium (i.e., for MEC in soil). Each remedial alternative comprises an individual technology or a combination of technologies. This chapter lists and briefly describes each of the developed remedial alternatives.

10.1 DEVELOPMENT OF ALTERNATIVES

10.1.1 The USEPA has established guidelines for the types of remedial alternatives that should be developed during the detailed analysis stage; they are listed in the NCP (40 Code of Federal Regulations [CFR] 300.430(a)(1)) and are summarized as follows:

- Use treatment to address the principal threats posed by a site, wherever practicable.
- Use engineering controls for low, long-term threats or where treatment is impracticable.
- Use a combination of methods, as appropriate, to achieve protection of human health and the environment.
- Use institutional controls to supplement engineering controls to prevent or limit exposure to hazardous substances, pollutants, or contaminants. The use of institutional controls shall not substitute for active response measures as the sole remedy unless such active measures are determined not to be practicable.
- Consider using innovative technologies.

10.1.2 NCP guidance further states that "the development and evaluation of alternatives shall reflect the scope and complexity of the remedial action under consideration" (40 CFR 300.430(e)). Land use is also a consideration in developing alternatives.

10.2 RATIONAL FOR ALTERNATIVE DEVELOPMENT

10.2.1 OVERVIEW

10.2.1.1 Remedial alternatives were developed based on the CSM, the RAO for the MRS (**Table 9.2**), the general response actions, and available detection, removal, and disposal technologies and process options for MEC, the remedial technologies retained after the technology evaluation (**Table 9.3**) were assembled into the following remedial action alternatives:

Alternative 1 – No Action

Alternative 2 – Public Education and Warning Signs (LUCs)

Alternative 3 – Surface MEC Removal and LUCs

Alternative 4 – Focused Surface and Subsurface MEC Removal and LUCs

Alternative 5 – Complete Surface and Subsurface MEC Removal (UU/UE)

10.2.1.2 Five-year reviews, as outlined in Section 121(c) of CERCLA, as amended by the Superfund Amendments and Reauthorization Act, and Section 300.430 (f) (ii) of the NCP, are required for sites (at least every 5 years) where hazardous substances, pollutants, or contaminants remain above levels that allow UU/UE following implementation of the remedy. Five-year reviews are not considered part of a remedy.

10.2.2 USING THE ARMY RISK MANAGEMENT METHOD TO EVALUATE ALTERNATIVES

10.2.2.1 A baseline risk assessment was conducted to evaluate potential explosive risk from MEC at the Fort Tuthill Small Arms Range North MRS. The assessment was conducted using risk matrices and methods from the *Final Study Paper: Decision Logic to Assess Risks Associated with Explosive Hazards, and to Develop Remedial Action Objectives (RAOs) for Munitions Response Sites* (USACE, 2017) in accordance with the memorandum titled "*Trial Period Extension for Risk Management Methodology (RMM) at Formerly Used Defense Sites (FUDS) Military Munitions Response Projects*" (DoD, 2019). The methodology and matrices are used to determine if unacceptable risk exists for MEC. The methodology also supports the development of RAOs to identify and evaluate remedial action alternatives in the Feasibility Study. The results of the RMM assessment for the Fort Tuthill Small Arms Range North MRS indicate the overall risk from explosive hazards is unacceptable for the MRS under current and future conditions (**Appendix I**).

10.2.2.2 The RMM (USACE, 2017) uses three matrices (Matrices 1 through 3) to support the risk evaluation for a range of risk scenarios. To complete the baseline assessment for explosive risk, input factors for the three matrices are reviewed and suitable categories are selected based on the baseline site conditions and assumptions for the proposed alternatives. The matrices are related to the three critical risk elements and are:

- **Likelihood of Encounter (Matrix 1)**, which is based on the input factors:
  - *Amount of MEC* (i.e., how much MEC is there at the site?)
  - *Access Conditions (frequency of use)* (i.e., how likely are human receptors to access the site based on access conditions and frequency of use?)
- **Severity of Incident (Matrix 2)**, which is based on the input factors:
  - *Likelihood of encounter* (see first bullet above)
  - *Severity Associated with Detonation of Specific Munitions* (i.e., if someone encounters MEC and it detonates, how many people might be injured and how seriously?)
- **Likelihood of Detonation (Matrix 3)**, which is based on the input factors:
  - *Sensitivity/Susceptibility to Detonation* (i.e., how sensitive is the fuzing of the MEC?)
  - *Likelihood to Impart Energy on an Item* (i.e., if MEC is encountered, what is the likelihood that energy will be imparted based on the known activities that take place at the site?)

10.2.2.3 A fourth matrix (Matrix 4) combines the results of the other matrices to differentiate acceptable versus unacceptable conditions regarding risk from explosive hazards:

- **Acceptable and Unacceptable Site Conditions (Matrix 4)**, which is based on the:
  - Outputs of Matrix 1 – Likelihood of Encounter and Matrix 2 – Severity of Incident
  - Likelihood of Detonation (i.e., output of Matrix 3)

10.2.2.4 Whether a remedial alternative achieves the established RAO is demonstrated by whether the alternative leads to an acceptable risk condition as defined by RMM Matrix 4, that is, whether the alternative changes unacceptable baseline risk conditions to acceptable risk conditions. This is achieved by assessing how each remedial alternative mitigates risk.

- Risk is mitigated by remedial alternatives that reduce the "Likelihood of Encounter". This can be accomplished by reducing the "Amount of MEC" via detection and removal, or by modifying the "Access Conditions (frequency of use)" via implementation of LUCs, or by a combination of the two.
- Risk is mitigated by remedial alternatives that address the "Likelihood to Impart Energy on an Item." This can be accomplished via implementation of LUCs.

10.2.2.5 The RMM and its application to this site are described in more detail in **Appendix G**.

10.2.3 RISK MANAGEMENT METHOD EVALUATION OF ALTERNATIVES

The RMM was used to evaluate if implementing the remedial alternatives developed for the NDNODS Fort Tuthill Small Arms Range MRS would result in an acceptable risk from MEC. An evaluation was conducted for both current conditions and a future unrestricted use scenario for each of the following alternatives:

Alternative 1 – No Action

Alternative 2 – Public Education and Warning Signs (LUCs)

Alternative 3 – Surface MEC Removal and LUCs

Alternative 4 – Focused Surface and Subsurface MEC Removal and LUCs

Alternative 5 – Complete Surface and Subsurface MEC Removal (UU/UE)

10.2.3.1 ALTERNATIVE 1 – NO ACTION

The risks associated with **Alternative 1 – No Action**, are the baseline risks established in the RI. Because Alternative 1 does not involve implementing any remedial actions, it would not permanently reduce or eliminate the MEC risk, and it would not change the MRS conditions from "Unacceptable" to "Acceptable".

10.2.3.2 ALTERNATIVE 2 – PUBLIC EDUCATION AND WARNING SIGNS (LUCS)

10.2.3.2.1 For **Alternative 2 – Land Use Controls**, the implementation of public education and warning signs would serve to limit human interaction with surface and subsurface UXO within the MRS by increasing the awareness of potential MEC hazards. The LUCs implemented under Alternative 2 would change the Decision Logic to Assess Risks' evaluation of the site conditions from "Unacceptable" to "Acceptable" in the Remainder of the MRS at the NDNODS Fort Tuthill Small Arms Range North MRS. This is based on the "Likelihood to Impart Energy on an Item" changing from "Modest" to "Inconsequential" (**Table I.1**). However, Implementing Alternative 2 would not change the site risk conditions for the Focused Area, site risk conditions would remain "Unacceptable", this is because the "Amount of MEC" in the Focused Area is greater than it is in the Remainder of MRS, and Implementing LUCs would not change the amount of MEC. Furthermore, the Park plans future development and increased recreational use of this area.

10.2.3.2.2 Implementing LUCs within the MRS would not change the amount of MEC or the access conditions; therefore, no changes were made in *Matrix 1: Likelihood of an Encounter*. Likewise, implementing LUCs would not significantly change the severity of an unplanned detonation, resulting in no changes to *Matrix 2: Severity of Incident*. Implementing LUCs as described would change human behavior thereby decreasing the "Likelihood to Impart Energy on an Item" in *Matrix 3: Likelihood of Detonation* from "Modest" to "Inconsequential." Based on the results from Matrices 1 through 3 the overall site risk conditions for the NDNODS Fort Tuthill Small Arms Range North MRS under current and anticipated future conditions would change from "Unacceptable" to "Acceptable" for the Remainder of MRS, but would remain "Unacceptable" for the Focused Area, as shown in *Matrix 4: Acceptable and Unacceptable Site Conditions*.

10.2.3.3 ALTERNATIVE 3 – SURFACE MEC REMOVAL AND LUCS

10.2.3.3.1 For **Alternative 3 – Complete Surface MEC Removal and LUCs**, the implementation of a complete surface MEC removal and LUCs would serve to reduce risks by removing surface MEC throughout the MRS and would limit human interaction with surface and subsurface UXO at the MRS by increasing the awareness of potential hazards. The actions implemented under Alternative 3 would change the Decision Logic to Assess Risks' evaluation of the site conditions from "Unacceptable" to "Acceptable" at the NDNODS Fort Tuthill Small Arms Range North MRS. This is based on the "Amount of MEC" changing from "Category III" to "Category IV" for the Focused Area and the "Likelihood to Impart Energy on an Item" changing from "Modest" to "Inconsequential" for both areas (**Table I.2**).

10.2.3.3.2 Implementing a complete surface MEC removal within the MRS would reduce the amount of MEC from "Category III" to "Category IV" in *Matrix 1: Likelihood of an Encounter* therefore changing the "Likelihood of Encounter" from "Likely" to "Occasional" to. Implementing Alternative 3 would not change the severity of an unplanned detonation, resulting in changes to *Matrix 2: Severity of Incident* only due to reducing the likelihood of encounter via source removal (Matrix 1). Implementing LUCs (public education and warning signs) would

change human behavior thereby changing the "Likelihood to Impart Energy on an Item" in *Matrix 3: Likelihood of Detonation* from "Modest" to "Inconsequential." Based on the results from Matrices 1 through 3 the overall site risk conditions for the Focused Area and Remainder of MRS at NDNODS Fort Tuthill Small Arms Range North MRS under current and anticipated future conditions would change from "Unacceptable" to "Acceptable" as shown in *Matrix 4: Acceptable and Unacceptable Site Conditions*. Regardless of the outcome of Matrix 4, the SPP Team agreed during SPP Meeting #4 (see meeting minutes in Appendix K) that Alternative 3 is not protective of human health for the Focused Area as it does not decrease the amount of MEC in the subsurface and there is future park development plans that are potentially intrusive in that area.

10.2.3.4 ALTERNATIVE 4 – FOCUSED SURFACE AND SUBSURFACE MEC REMOVAL AND LUCS

10.2.3.4.1 For **Alternative 4 – Focused Surface and Subsurface MEC Removal and LUCs**, the implementation of a 25-acre "focused" surface and subsurface MEC removal and LUCs would serve to reduce risks by removing surface and subsurface MEC throughout a portion of the MRS and would limit human interaction with surface and subsurface UXO by increasing the awareness of potential hazards. The actions implemented under Alternative 4 would change the Decision Logic to Assess Risks' evaluation of the site conditions from "Unacceptable" to "Acceptable" at the NDNODS Fort Tuthill Small Arms Range North MRS. This is based on the "Amount of MEC" changing from "Category IV" to "Category V" and the "Likelihood to Impart Energy on an Item" changing from "Modest" to "Inconsequential" (**Table I.3**).

10.2.3.4.2 Implementing a "focused" surface and subsurface MEC removal within the MRS would reduce the amount of MEC from "Category III" to "Category V" in *Matrix 1: Likelihood of an Encounter* therefore changing the "Likelihood of Encounter" from "Likely" to "Seldom." Implementing Alternative 4 would not change the severity of an unplanned detonation, resulting in changes to *Matrix 2: Severity of Incident* only due to reducing the likelihood of encounter via source removal (Matrix 1). Implementing LUCs (public education and warning signs) would change human behavior thereby changing the "Likelihood to Impart Energy on an Item" in *Matrix 3: Likelihood of Detonation* from "Modest" to "Inconsequential." Based on the results from Matrices 1 through 3 the overall site risk conditions for the Focused Area and Remainder of MRS at NDNODS Fort Tuthill Small Arms Range North MRS under current and anticipated future conditions would change from "Unacceptable" to "Acceptable" as shown in *Matrix 4: Acceptable and Unacceptable Site Conditions*.

10.2.3.5 ALTERNATIVE 5 – COMPLETE SURFACE AND SUBSURFACE MEC REMOVAL (UU/UE)

10.2.3.5.1 For **Alternative 5 – Complete Surface and Subsurface MEC Removal (UU/UE)**, the implementation of a complete surface and subsurface MEC removal would serve to reduce risk by removing all surface and subsurface MEC throughout the MRS. The MEC removal implemented under Alternative 5 would change the Decision Logic to Assess Risks' evaluation of the site conditions from "Unacceptable" to "Acceptable" at the NDNODS Fort Tuthill Small Arms Range North MRS. This is based on the "Amount of MEC" changing from "Category IV" to "Category VI (Least)" (**Table I.4**).

10.2.3.5.2 Implementing a complete surface and subsurface MEC removal within the MRS would reduce the amount of MEC from "Category III" for the Focused Area and "Category V" for the Remainder of MRS to "Category VI (Least)" for both areas in *Matrix 1: Likelihood of an Encounter* therefore changing the "Likelihood of Encounter" from "Likely" and "Seldom" to "Unlikely." Implementing these remedial actions would not change the severity of an unplanned detonation, resulting in changes to *Matrix 2: Severity of Incident* only due to reducing the likelihood of encounter via source removal (Matrix 1). Implementing Alternative 5 would not result in any changes to human behavior, however the MEC would be mitigated, therefore the "Likelihood to Impart Energy on an Item" in *Matrix 3: Likelihood of Detonation* would change from "Modest" to "Inconsequential". Based on the results from Matrices 1 through 3 the overall site risk conditions for the NDNODS Fort Tuthill Small Arms Range North MRS under current and anticipated future conditions would change from "Unacceptable" to "Acceptable" as shown in *Matrix 4: Acceptable and Unacceptable Site Conditions*.

10.3 ALTERNATIVE DESCRIPTIONS

10.3.1 ALTERNATIVE 1 – NO ACTION

The NCP requires that a No Action alternative be evaluated to provide a baseline for comparison to other alternatives. This alternative provides no actions to protect human health or the environment at the MRS. This alternative, if implemented, would involve continued use of the MRS in its current condition. As this is required per the NCP, no preliminary screening is necessary, and this alternative is retained for the detailed analysis of alternatives in Chapter 11.

10.3.2 ALTERNATIVE 2 – PUBLIC EDUCATION AND WARNING SIGNS (LUCS)

10.3.2.1 Alternative 2 would not remove any MEC from the MRS. Rather, it would focus on modifying human behavior through public education and warning signs. To educate the receptors of potential explosive hazards, educational pamphlets would be developed and distributed to the public at the Park and warning signs would be installed at Park access points and kiosks. By increasing awareness of the explosive hazards and of the proper reporting procedures to use if a suspected MEC item is observed, receptor behavior would be modified.

10.3.2.2 The signs and pamphlets would stress the importance of the "3Rs" — Recognize, Retreat, and Report. Any MEC that is found during current and future activities should be left undisturbed and should be reported to the appropriate authorities, per the "3Rs." The focus of educational pamphlets should be the prevention of handling of suspected MEC and the reporting of suspected MEC. Based on the number of people who access the Park daily an estimated 5,000 pamphlets will be produced yearly. The signs would reinforce the link between appropriate access and safety. Annual maintenance would be necessary for the signs. This alternative does not achieve UU/UE. Five-Year Reviews would be conducted to ensure that the LUCs remain protective of potential human receptors. The components of this alternative are summarized in Table 10.1.

Table 10.1 Summary of Alternative 2

Alternative 2	Important Actions
Public Education	Development and distribution of an educational pamphlet including relevant information on the potential presence of MEC within the MRS and the necessary safety precautions to be taken within those areas. Annual printing and distribution of educational pamphlets: • 5,000 placed at Park locations (such as visitors center, kiosks, and trailheads)
Warning Signs	Installation of warning signs at Park access points and kiosks to include relevant information on the potential presence of MEC within the MRS and the necessary safety precautions to be taken within those areas. Initial installation and annual maintenance warning signs: • 25 warning signs initially installed at Park locations (access points, kiosks, visitor center) • 5 replacement signs installed annually as part of sign maintenance

10.3.3 ALTERNATIVE 3 – SURFACE MEC REMOVAL AND LUCS

10.3.3.1 Alternative 3 would use instrument-aided surface sweeps to identify and remove potential MEC exposed or at the ground surface within the 100-acre MRS. LUCs consisting of educational controls (public education) and warning signs would be required to mitigate the potential for human exposure to remaining subsurface MEC in the MRS. This alternative does not achieve UU/UE.

10.3.3.2 MEC Detection would be the first step in surface MEC removal, which would be accomplished with an instrument-aided surface sweep. UXO-qualified personnel would systematically walk the MRS and mark, identify, and record the locations of all MEC found on the surface for removal or subsequent disposal. The search would be conducted with a handheld analog magnetometer or electromagnetic (EM) detector such as the Schonstedt GA52-CX, White's All Metals Detector, Garrett AT Max, or similar instruments. The operator would systematically search sweep lanes within a pre-established grid network using the magnetometer to identify anomalies. The grid network would be established for 100% coverage of the 100-acre MRS. If the instrument indicates a response but the source item is not found on or just below the ground surface, the UXO Technician would move on without extensive digging into the subsurface.

10.3.3.3 MEC Removal on the ground surface would be performed by UXO-qualified personnel investigating visually detected anomalies confirmed by the handheld analog instruments. If the MEC is partially exposed, or protruding above the surface, limited digging with hand tools would be conducted until the item could be verified as MEC or MD. It is not anticipated that removal activities under Alternative 3 would greatly disturb the environment, since only potential MEC on or just below the ground surface (1-2 inches in loose soil) would be investigated. An exclusion zone (EZ) must be maintained during any surficial digging of surface anomalies or demolition actions which could result in closure of parts of the Park.

10.3.3.4 Demolition would be performed on all MEC. Any MEC would be evaluated by the UXO-qualified personnel to determine whether it is acceptable to move or if it would be BIP. MEC considered acceptable to move would be transported to an appropriate location for demolition. If a MEC item were not acceptable to move, then BIP would be unavoidable and evacuations within the EZ would be necessary. All notifications and procedures for demolition operations would be conducted in accordance with the procedures established in the Remedial Action Work Plan (RAWP). Depressions/craters created by the detonation would be backfilled and restored, as appropriate. Hazardous MEC items determined to be acceptable to move would be stockpiled and consolidated for demolition with other MEC items that are unacceptable to move, where practicable. All MD would be collected for off-site disposal for smelting and recycling. NMRD recovered during the removal action would be transported off site for disposal or recycling as non-hazard municipal waste. MC sampling for explosives would be limited to post-BIP sampling following demolition actions

10.3.3.5 LUCs are included in this alternative because MEC would potentially remain in the subsurface in the MRS. Educational controls (public education) and warning signs would be necessary to reduce the likelihood of human interaction with MEC. LUCs would be the same as described in Alternative 2. Five-Year Reviews would be conducted to ensure that the LUCs remain protective of potential human receptors. The components of this alternative are summarized in Table 10.2.

Table 10.2 Summary of Alternative 3

Alternative 3	Important Actions
Surface Clearance	Surveying, vegetation clearance (only where necessary), surface clearance and removal of MEC with analog magnetometers, and disposal of any MEC and MD. Cost assumptions include: • NDNODS Fort Tuthill Small Arms Range North MRS LUA: 100% of this area requires surface clearance – 100 acres. Details are provided in Appendix J for the cost assumptions.
LUCs	Development and distribution of an educational pamphlet including relevant information on the potential presence of MEC within the MRS and the necessary safety precautions to be taken within those areas. Annual printing and distribution of educational pamphlets: • 5,000 placed at park locations (such as visitors center, kiosks, and trailheads) Installation of warning signs at park access points and kiosks to include relevant information on the potential presence of MEC within the MRS and the necessary

	safety precautions to be taken within those areas. Initial installation and annual maintenance warning signs: • 25 warning signs initially installed at park locations (access points, kiosks, visitor center) • 5 replacement signs installed annually as part of sign maintenance

10.3.4 ALTERNATIVE 4 – FOCUSED SURFACE AND SUBSURFACE MEC REMOVAL AND LUCS

10.3.4.1 Alternative 4 is a combination of Alternative 2 and Alternative 5 (below) and would use instrument-aided surface sweeps along with DGM and AGC methods within a 25-acre "focus" area. The "focus" area includes the impact area, both historical locations where 2.36-inch bazooka rockets finds were previously reported, the locations where RI MD findings (57mm HE recoilless rifle fragments and 60mm HE mortar fragments) were identified (Figures 3.1 and 3.2), plus a buffer area. Following field-delineating the 25-acre "focus" area and establishing a subgrid network for progress tracking purposes, surface sweeps would be conducted (to remove metallic clutter) followed by DGM and AGC surveys, and intrusive removal actions would be conducted. LUCs, consisting of educational controls (public education) and warning signs would be implemented to mitigate the potential for human exposure to remaining potential MEC hazards within the balance of the MRS. This alternative does not achieve UU/UE for the entire MRS.

10.3.4.2 Instrumented-aided surface sweeps would be conducted first followed by DGM and AGC over the selected portions of the MRS. MEC Detection for surface MEC removal would be accomplished with an instrument-aided surface sweep. UXO-qualified personnel would systematically walk the pre-established subgrid network within the "focus" area of the MRS and mark, identify, and record the locations of all MEC found on the surface for removal or subsequent disposal. The search would be conducted with a handheld analog magnetometer or EM detector such as the Schonstedt GA52-CX, White's All Metals Detector, Garrett AT Max, or similar instruments. The operator would systematically search sweep lanes within subgrids using the magnetometer to identify anomalies. The subgrid network would be established for 100% coverage of the 25-acre "focus" area of the MRS. If the instrument indicates a response but the item is not found on or just below the ground surface, the UXO Technician would move on without extensive digging into the subsurface but note the location in the logbook for potential subsequent intrusive investigation. Following completion of surface sweeps, DGM and AGC surveys would be implemented followed by intrusive removal actions.

10.3.4.3 MEC subsurface detection within the "focus" area of the MRS would be conducted using DGM with equipment such as EM61 or similar sensors. Use of DGM would allow rapid data collection, resulting in a digital, georeferenced map of anomaly densities. The data would be collected, processed, evaluated, and analyzed to select anomalies for AGC investigation. Where an isolated target anomaly is present, the coordinates would be located, and the anomaly would be "reacquired" to precisely pinpoint its location with a pin flag for subsequent removal. AGC detection will be verified using QA/QC and validation targets. QA seeding is assumed to be conducted in tandem with the survey and completed by the government. A Schonstedt GA52-CX analog magnetometer, Garrett AT Max, or similar instrument, would be used to investigate inaccessible areas that could not be mapped with the DGM sensor. There are no terrain features of concern since the area is primarily rolling hills with open vegetation. Analog detectors can detect the munitions of interest at the recovery depths specified in the RAO. Analog detection will be verified using QC and validation seeds.

10.3.4.4 MEC Removal would be performed by manually using shovels to excavate the soil in 1 ft depth intervals until the RAO depth of 60 cm bgs is attained. Note that in the Remedial Action Work Plan (RAWP) a different depth may be established for the berm based on the possibility of the berm topography being altered after the period of munitions use at the site and the possibility of future park development altering the topography of the berm at a depth greater than 60 cm. Once the desired depth has been reached, the excavation bottom and sides would be surveyed with a combination of analog detectors and DGM/AGC sensors to verify that all anomalies potentially represented subsurface MEC has been removed. During excavation actions, all nonessential personnel would be evacuated beyond the required EZs and temporary closure of parts of the Park may be required. Excavation areas would be backfilled and re-graded using the native soil verified as free of MEC and MD.

10.3.4.5 Demolition would be performed on all MEC. Any MEC would be evaluated by the UXO-qualified personnel to determine whether it is acceptable to move or if it would be BIP. MEC considered acceptable to move would be transported to an appropriate location for demolition. If an MEC item were not acceptable to move, then BIP would be unavoidable and evacuations within the EZ would be necessary. All notifications and procedures for demolition operations would be conducted in accordance with the procedures established in the RAWP. Depressions/craters created by the detonation would be backfilled and restored, as appropriate. Hazardous MEC items determined to be acceptable to move would be stockpiled and consolidated for demolition with other MEC items that are unacceptable to move, where practicable. All MD would be collected for off-site disposal for smelting and recycling. NMRD recovered during the removal action would be transported off site for disposal or recycling as non-hazard municipal waste. MC sampling for explosives would be limited to post-BIP sampling following demolition actions.

10.3.4.6 LUCs are included in this alternative because MEC would potentially remain in the subsurface in the MRS. Educational controls (public education) and warning signs would be necessary to reduce the likelihood of human interaction with MEC. LUCs would be the same as described in Alternative 2. Five-Year Reviews would be conducted to ensure that the LUCs remain protective of potential human receptors. The components of this alternative are summarized in Table 10.3.

Table 10.3 Summary of Alternative 4

Alternative 4	Important Actions
Focused Surface and Subsurface Clearance	Vegetation clearance, surface and subsurface removal of MEC, utilizing DGM and AGC detection methods, and disposal of any MEC and MD. Cost assumptions include: • Surface removal over 100% of the 25-acre “focus” area. • Subsurface removal over 100% of the 25-acre “focus” area. Details are provided in Appendix J for the cost assumptions.
LUCs	Development and distribution of an educational pamphlet including relevant information on the potential presence of MEC within the MRS and the necessary safety precautions to be taken within those areas. Annual printing and distribution of educational pamphlets: • 5,000 placed at Park locations (such as visitors center, kiosks, and trailheads) Installation of warning signs at park access points and kiosks to include relevant information on the potential presence of MEC within the “focused” portion of the MRS and the necessary safety precautions to be taken within those areas. Initial installation and annual maintenance warning signs: • 25 warning signs initially installed at Park locations (access points, kiosks, visitor center) • 5 replacement signs installed annually as part of sign maintenance

10.3.5 ALTERNATIVE 5 – COMPLETE SURFACE AND SUBSURFACE CLEARANCE (UU/UE)

10.3.5.1 Alternative 5 would accomplish MEC detection using DGM and AGC methods and MEC removal by intrusive investigation of TOI over the entire 100-acre MRS.

10.3.5.2 Preparatory Activities consist of vegetation clearance. Vegetation and trees up to 4-inch diameter would need to be removed prior to collection of DGM data to within 6 inches of the ground surface. Areas

of thick groundcover would be removed to provide visibility for the safety of the UXO-qualified personnel. The anomaly reduction would be completed using analog detectors.

10.3.5.3 MEC Detection would be accomplished with the goal of achieving 100% coverage of the MRS with DGM using EM61 or similar sensors. Use of DGM would allow rapid data collection, resulting in a digital, georeferenced map of anomaly densities in the MRS. Under Alternative 5, the data would be collected, processed, evaluated, and analyzed to select anomalies for AGC investigation. Where an isolated target anomaly is present, the coordinates would be located, and the anomaly would be "reacquired" to precisely pinpoint its location with a pin flag for subsequent removal. AGC detection will be verified using QA/QC and validation targets. QA seeding is assumed to be conducted in tandem with the survey and completed by the government. A Schonstedt GA52-CX analog magnetometer, Garrett AT Max, or similar instrument, would be used to investigate inaccessible areas that could not be mapped with the DGM sensor (i.e., over water features that limits data collection or where utility lines present interference [expected to be very minimal]). There are no terrain features of concern since the area is primarily rolling hills with open vegetation. Analog detectors can detect the munitions of interest at the recovery depths specified in the RAO. Analog detection will be verified using QC and validation seeds.

10.3.5.4 MEC Removal would be performed by manually using shovels to excavate the soil in 1 ft depth intervals until the RAO depth of 60 cm bgs is attained. . Note that in the Remedial Action Work Plan (RAWP) a different depth may be established for the berm based on the possibility of the berm topography being altered after the period of munitions use at the site and the possibility of future park development altering the topography of the berm at a depth greater than 60 cm. Once the desired depth has been reached, the excavation bottom and sides would be surveyed with a combination of analog detectors and DGM/AGC sensors to verify that all anomalies potentially represented subsurface MEC has been removed. During excavation actions, all nonessential personnel would be evacuated beyond the required EZs and temporary closure of parts of the Park may be required. Excavation areas would be backfilled and re-graded using the native soil verified as free of MEC and MD.

10.3.5.5 Demolition would be performed on all MEC. Any MEC would be evaluated by the UXO-qualified personnel to determine whether it is acceptable to move or if it would be BIP. MEC considered acceptable to move would be transported to an appropriate location for demolition. If an MEC item were not acceptable to move, then BIP would be unavoidable and evacuations within the EZ would be necessary. All notifications and procedures for demolition operations would be conducted in accordance with the procedures established in the RAWP. Depressions/craters created by the detonation would be backfilled and restored, as appropriate. Hazardous MEC items determined to be acceptable to move would be stockpiled and consolidated for demolition with other MEC items that are unacceptable to move, where practicable. All MD would be collected for off-site disposal for smelting and recycling. NMRD recovered during the removal action would be transported off site for disposal or recycling as non-hazard municipal waste. MC sampling for explosives would be limited to post-BIP sampling following demolition actions.

10.3.5.6 UU/UE Conditions will be assessed. The depths that MEC is detected and removed and whether 100% coverage was attained will be evaluated post-removal to verify that UU/UE is achieved. UU/UE would also require that all ROE is granted or renewed for 100% of the MRS. If UU/UE is not achieved, LUCs as described in Alternative 2 would be implemented. The components of this alternative are summarized in **Table 10.4**.

Table 10.4 Summary of Alternative 4

Alternative 4	Important Actions
Complete Surface and Subsurface Clearance	Vegetation clearance, surface and subsurface removal of MEC, utilizing DGM and AGC detection methods, and disposal of any MEC and MD. Cost assumptions include: • Surface removal over 100% of the 100-acre MRS. • Subsurface removal over 100% of the 100-acre MRS. Details are provided in Appendix J for the cost assumptions.

11.0 Detailed Analysis of Remedial Alternatives

11.1 INTRODUCTION

11.1.1 The purpose of the detailed analysis is to evaluate and compare each of the alternatives that were developed in the previous chapter (**Subchapter 10.2**). This analysis will help to identify the most permanent solution consistent with current and future land use (see **Subchapter 2.5**) as determined by the criteria specified in the NCP (40 CFR 300.430).

11.1.2 Section 300.430(e) of the NCP lists nine CERCLA criteria against which each remedial alternative must be assessed. The acceptability or performance of each alternative against the criteria is evaluated individually so that relative strengths and weaknesses can be identified. The criteria are as follows:

1) Overall protection of Human Health and the Environment
2) Compliance with ARARs
3) Long-term effectiveness and permanence
4) Reduction of toxicity, mobility, or volume through treatment (TMV)
5) Short-term effectiveness
6) Implementability
7) Cost
8) State acceptance
9) Community acceptance

11.1.3 The NCP [Section 300.430(f)] states that the first two criteria, protection of human health and the environment and compliance with ARARs, are "threshold criteria" that must be met by the selected remedial action unless a waiver is granted under Section 121(d)(4) of CERCLA. The next five criteria are "primary balancing criteria," and the tradeoffs within this group must be balanced. The preferred alternative will be the alternative that is protective of human health and the environment, is ARAR-compliant, and provides the best combination of primary balancing attributes. The final two criteria, state and community acceptance, are "modifying criteria," which are based on the degree of acceptance from the local public and from state agencies regarding the implementation of alternatives and are evaluated following the 30-day public comment period on the PP and during DD preparation. The following sections describe each of the evaluation criteria and the evaluation process used for performing the analysis.

11.2 EVALUATION CRITERIA

11.2.1 THRESHOLD CRITERIA

Threshold criteria are requirements that each alternative must meet or have specifically waived to be eligible for selection. There are two threshold criteria: Overall Protection of Human Health and the Environment and Compliance with ARARs, as described below.

11.2.1.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The selected alternative must adequately protect human health and the environment from unacceptable risks posed by MEC. The threshold criterion will be met if the unacceptable risks associated with the human exposures to MEC are eliminated, reduced, or controlled through treatment, engineering, or LUCs, and if the remedial action is protective of the environment. The RMM was used to evaluate whether risks are acceptable or unacceptable for each remedial alternative.

11.2.1.2 COMPLIANCE WITH ARARS

Compliance with ARARs is a threshold criterion that must be met by the proposed remedial alternative. The remedial alternative will meet this criterion if all ARARs are met by the alternative. ARARs identified for the remedial actions at the NDNODS Fort Tuthill Small Arms Range North MRS consist of RCRA Subpart X which would apply to all consolidated munition destruction events as part of Alternatives 3 through 5. For those ARARs that are not met, a determination will be made as to whether a waiver is appropriate. It should be

noted that the ARARs presented in this FS are preliminary. Final ARARs and compliance determinations will be made in the DD.

11.2.2 BALANCING CRITERIA

Primary balancing criteria are those that form the basis for comparison among alternatives that meet the threshold criteria. The five primary balancing criteria are Long-term Effectiveness and Permanence, Reduction of TMV through Treatment, Short-term Effectiveness, Implementability, and Cost, as described below. Remedies are required to be permanent (e.g., removal of MEC) to the maximum extent practicable and to be cost effective. The five balancing criteria are weighed against each other to determine which remedies meet these criteria. The NCP explains that in general, preferential weight is given to alternatives that offer advantages in terms of the reduction of TMV through treatment, and that achieve long-term effectiveness and permanence. However, the NCP also recognizes that some contamination problems will not be suitable for treatment and permanent remedies. The balancing process considers that preference and weighs the proportionality of costs to effectiveness to select one or more remedies that are cost effective. The final risk management decision made for the site is one that determines which cost-effective remedy offers the best balance of all criteria to achieve permanence to the maximum extent practicable.

11.2.2.1 LONG-TERM EFFECTIVENESS AND PERMANENCE

The long-term effectiveness and permanence criterion evaluates the degree to which an alternative permanently reduces or eliminates the potential for MEC risks. This criterion also evaluates the magnitude of residual risk with the alternative in place, and the adequacy and reliability of controls, such as containment systems and ICs, necessary to manage residual risk.

11.2.2.2 REDUCTION OF TMV THROUGH TREATMENT

This criterion addresses the statutory preference for selecting remedies that employ treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume of the hazardous substances. The following factors are considered:

- The amount of hazardous materials that will be destroyed or treated;
- The degree of expected reduction in toxicity, mobility, or volume;
- The degree to which the treatment will be irreversible;
- The type and quantity of treatment residuals that will remain following treatment;
- Treatment processes the remedial alternatives employ and the materials they will treat; and
- Degree to which treatment reduces the inherent hazards posed by the principal threats at the MRS.

For munitions response projects, excavation followed by explosive demolition of MEC is considered to reduce the TMV through treatment.

11.2.2.3 SHORT-TERM EFFECTIVENESS

The short-term effectiveness criterion addresses the potential consequences and risks of an alternative during the implementation phase. The following factors will be addressed:

- Protection of the community during the remedial action, such as protection from intentional and unintentional detonations, transportation of contaminated materials, and air-quality impacts from on-site disposal or treatment;
- Potential impacts on workers during the remedial action and the effectiveness and reliability of any protective measures;
- Environmental impacts of the remedial action and the effectiveness and reliability of mitigating measures; and

- Time required to achieve the remedial response objectives.

11.2.2.4 IMPLEMENTABILITY

The implementability criterion evaluates the difficulty of implementing a specific cleanup action alternative both technically and administratively. Technical implementability refers to the ability to construct, reliably operate, and meet technology-specific regulations for process options until a remedial action is complete. It also includes operation, maintenance, replacement, and monitoring of technical components of an alternative, if required, into the future after then remedial action is complete. Administrative feasibility refers to the ability to obtain approvals from other offices and agencies; the availability of treatment, storage, and disposal services and capacity; and the requirements for, and availability of, specific equipment and technical specialists.

11.2.2.5 COST

11.2.2.5.1 The cost criterion evaluates the financial cost to implement the alternative. This includes direct, indirect, and long-term operation and maintenance costs (30-year estimate). For the purposes of evaluating and comparing alternatives as specified in the RI/FS Guidance (USEPA, 1988), a period of 30 years is used for estimating O&M costs. Direct costs are those costs associated with the implementation of the alternative. Indirect costs are those costs associated with administration, oversight, and contingencies. For periodic costs, such as five-year reviews and operations and maintenance (O&M), the estimate is based on a project life of 30 years.

11.2.2.5.2 Cost estimates presented are order-of-magnitude level estimates. Based on a variety of information, including productivity estimates (based on site conditions), cost estimating guides, and prior experience at the Site. The actual costs will depend on true labor rates, actual weather conditions, final project scope, and other variable factors. A present value analysis is used to evaluate costs (capital and O&M) which occur over different periods. The total present value (TPV) is the amount needed to be set aside at the initial point in time (base year) to assure that funds will be available in the future as they are needed. The discount rate of 7 percent per the USEPA guidance, A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, (USEPA, 2000) was used to estimate TPV.

11.2.2.5.3 Remedial action alternative cost estimates for the detailed analysis are intended to provide a measure of total resource costs over time (i.e., “life cycle costs”) associated with any given alternative. As such, these estimates generally are based on more detailed information and should achieve a greater level of accuracy than screening-level estimates. The detailed analysis level accuracy range of –30 to +50 percent means that, for an estimate of $100,000, the actual cost of an alternative is expected to be between $70,000 and $150,000 (USEPA, 2000).

11.2.3 MODIFYING CRITERIA

Community and State acceptance of the remedy can play a role in weighing the balance between remedies that are cost effective and meet other criteria. The SPP process and public involvement activities help to provide an understanding of these criteria even though the PP has not yet been issued. The community and State acceptance criteria are based on the degree of assumed acceptance from the local public and from State agencies regarding the implementation of alternatives. These criteria cannot be fully evaluated and assessed until comments on the FS and the PP are received.

11.3 INDIVIDUAL ANALYSIS OF ALTERNATIVES

The alternatives developed in **Chapter 10** that were retained for detailed analysis are listed below (only the “No Action” alternative and those alternatives which were evaluated as “acceptable” following implementation of the remedy as summarized in **Subchapter 10.4**):

Alternative 1 – No Action

Alternative 2 – Public Education and Warning Signs (LUCs)

Alternative 3 – Complete Surface MEC Removal and LUCs

Alternative 4 – Focused Surface and Subsurface MEC Removal and LUCs

Alternative 5 – Complete Surface and Subsurface MEC Removal (UU/UE)

The following sections provide a detailed analysis of these alternatives according to the nine NCP criteria. If an alternative does not meet the threshold criteria it will not be retained for further analysis and will be removed from consideration as an alternative. The final two criteria, state and community acceptance will be evaluated after the PP.

11.3.1 ALTERNATIVE 1 – NO ACTION

A description of this alternative is provided in Subchapter 10.3.1.

11.3.1.1 ASSESSMENT OF THRESHOLD CRITERIA

This alternative assumes no action would be taken to address the RAO. This alternative is provided as a baseline for comparison to the other remedial alternatives, as required under CERCLA and the NCP. Alternative 1 does not reduce risk due to the presence of surface and subsurface MEC, since no remedial activities would be implemented to mitigate those risks at the NDNODS Fort Tuthill Small Arms Range North MRS. Because no actions would be implemented under Alternative 1, none of the identified ARARs are triggered. This alternative is not protective of human health and the environment and does not meet the criterion. As such, this alternative has been removed from consideration for applicability for this MRS but is retained for comparison of alternatives as required.

11.3.2 ALTERNATIVE 2 – PUBLIC EDUCATION AND WARNING SIGNS (LUCS)

A description of this alternative is provided in Subchapter 10.3.2.

11.3.2.1 ASSESSMENT OF THRESHOLD CRITERIA

Alternative 2 would use LUCs to reduce and manage MEC risk at the NDNODS Fort Tuthill Small Arms Range North MRS. Potential hazards associated with direct contact and contact through intrusive activities. This alternative is protective of human health and the environment and meets the criterion. The risk for the "Remainder of MRS" area would be revised to "acceptable" after implementation of this alternative, this alternative does not achieve "acceptable" site risk conditions for the "Focused Area" (Appendix I). Because no MEC removal or demolition actions would be implemented under Alternative 2, none of the identified ARARs are triggered.

11.3.2.2 ASSESSMENT OF BALANCING CRITERIA

11.3.2.2.1 Successful implementation of the remedial actions under Alternative 2 would be effective at reducing risk over the long-term due to the increase in awareness of potential hazards through warning signs and public education even though MEC may remain on the ground surface and in the subsurface at the MRS. The long-term effectiveness would be ensured through continued annual implementation of LUCs in the form of public education of any potential remaining hazards on-site and maintenance of warning signs. Five-Year Reviews would be conducted to ensure that the LUCs remain protective of any potential human receptors.

11.3.2.2.2 No treatment is employed as part of the Alternative 2. This alternative would not reduce the toxicity, mobility, or volume of MEC remaining in the surface and subsurface of the MRS, therefore this alternative would not satisfy the statutory preference for employing treatment as a principal element.

11.3.2.2.3 Implementation of Alternative 2 would result in short-term hazards to workers involved with the installation of warning signs because of the increased likelihood of MEC exposure. However, these hazards would be managed using industry standard safety procedures (e.g., using qualified UXO personnel, enforcement of safe separation distances, engineering controls, etc.), which would also minimize any associated potential risks to the surrounding community. This alternative would not cause any adverse short-term effects on the environment. The estimated timeframe for implementing Alternative 2 is 1 week. Maintenance of warning signs and distribution of public education materials will continue to be implemented annually.

11.3.2.2.4 All technologies and methods involved in implementing Alternative 2 are well established and would be technically and administratively implementable. The services and materials required to implement the work are readily available: (1) Handheld analog detectors can easily be obtained to support the installation of warning signs; and (2) UXO-qualified personnel who are specially trained for EOD work and who would support and conduct any remedial actions. Conversely, Alternative 2 is dependent on landowner participation, ROEs must be granted or renewed for the work to occur. Although equipment and personnel required to complete Alternative 2 are readily available, if implementation of the alternative throughout the MRS is limited by ROE, the overall effectiveness would decrease.

11.3.3.2.5 The TPV cost of implementing Alternative 2 at the NDNODS Fort Tuthill Small Arms Range North MRS is estimated as $507,195 (**Table J.2** and **Appendix J**). Alternative 2 would not achieve UU/UE and Five-Year Reviews would be required.

11.3.3 ALTERNATIVE 3 – COMPLETE SURFACE MEC REMOVAL AND LUCS

A description of this alternative is provided in **Subchapter 10.3.3.**

11.3.3.1 ASSESSMENT OF THRESHOLD CRITERIA

11.3.3.1.1 The remedial actions included in Alternative 3 would remove all surface MEC at the NDNODS Fort Tuthill Small Arms Range North MRS and LUCs would be used to manage the remaining risk from MEC in the subsurface. The risk for the MEC contaminated area would be revised to "acceptable", after implementation of this alternative (**Appendix I**). Regardless of the outcome of the RMM evaluation in Appendix I, the SPP Team agreed during SPP Meeting #4 (see meeting minutes in Appendix K) that Alternative 3 is not protective of human health for the Focused Area as it does not decrease the amount of MEC in the subsurface and there is future park development plans that are potentially intrusive in that area.

11.3.3.1.2 Investigation-derived waste material produced would be subject to the action-specific ARAR, RCRA (Subpart X). All materials resulting from MEC disposal activities would be inspected, certified as material documented as safe (MDAS), transported under chain of custody control, and disposed by smelting.

11.3.3.2 ASSESSMENT OF BALANCING CRITERIA

11.3.3.2.1 Successful implementation of the remedial actions under Alternative 3 would be effective at reducing risk over the long-term due to the removal of surface MEC throughout the MRS and the increase in awareness of potential hazards through warning signs and public education. Implementing Alternative 3 may result in some MEC remaining in the subsurface and in locations where removal was not able to be implemented (e.g., where ROE is not obtained). The long-term effectiveness would be ensured through continued annual implementation of LUCs in the form of public awareness measures of any potential remaining hazards on-site and maintenance of warning signs. Five-Year Reviews would be conducted to ensure that the LUCs remain protective of potential human receptors.

11.3.3.2.2 Alternative 3 would result in complete removal of MEC in the surface of the MRS as defined in **Table 10.2**. Alternative 3 includes the intentional removal and/or treatment of MEC (demolition), thus satisfying the statutory preference for employing treatment as a principal element.

11.3.3.2.3 Implementation of Alternative 3 would result in short-term hazards to workers involved with the surface MEC removal activities or the installation of warning signs because of the increased likelihood of MEC exposure. Evacuation of non-essential personnel would be necessary for some locations during MEC removal. However, these hazards would be managed using industry standard safety procedures (e.g., using qualified UXO personnel, enforcement of safe separation distances, engineering controls, etc.), which would also minimize any associated potential risks to the surrounding community. This alternative would not cause any adverse short-term effects on the environment. The estimated timeframe for implementing the removal action portion of Alternative 3 is 8 weeks. Maintenance of warning signs and distribution of public education materials will continue to be implemented annually.

11.3.3.2.4 All technologies and methods involved in implementing Alternative 3 are well established and would be technically and administratively implementable. The services and materials required to implement the work are readily available: (1) Handheld analog detectors can easily be obtained to support the MEC

removal effort; and (2) UXO-qualified personnel who are specially trained for EOD work and who would support and conduct any MEC removal would be readily available. Conversely, Alternative 3 is dependent on land-owner participation, ROEs must be granted or renewed for the work to occur. Although equipment and personnel required to complete Alternative 3 are readily available, if implementation of the alternative throughout the MRS is limited by ROE, the overall effectiveness would decrease.

11.3.3.2.5 The TPV cost of implementing Alternative 3 at the NDNODS Fort Tuthill Small Arms Range North MRS is estimated as $1,830,128 (**Table J.3** and **Appendix J**). Alternative 3 would not achieve UU/UE and Five-Year Reviews would be required.

11.3.4 ALTERNATIVE 4 – FOCUSED SURFACE AND SUBSURFACE MEC REMOVAL AND LUCS

A description of this alternative is provided in **Subchapter 10.3.4**.

11.3.4.1 ASSESSMENT OF THRESHOLD CRITERIA

11.3.4.1.1 The remedial actions associated with Alternative 4 would serve to eliminate human interaction with MEC by removing surface and subsurface MEC within the 25-acre "focused" area of the NDNODS Fort Tuthill Small Arms Range North MRS. This alternative is protective of human health and the environment and meets the criterion. The risk for the MRS Focused Area and Remainder of MRS would be revised to "acceptable", after implementation of this alternative (**Appendix I**).

11.3.4.1.2 Investigation-derived waste material produced would be subject to the action-specific ARAR, RCRA (Subpart X). All materials resulting from MEC disposal activities would be inspected, certified as MDAS, transported under chain of custody control, and disposed by smelting.

11.3.4.2 ASSESSMENT OF BALANCING CRITERIA

11.3.4.2.1 Successful implementation of the remedial actions under Alternative 4 would be effective at reducing risk over the long-term through both surface and subsurface removal of potential MEC within the 25-acre "focused" area. The depth of potential MEC within the MRS is presented in **Table 10.3**. Implementing Alternative 4 may result in some MEC remaining in areas outside the "focused" area where no MEC removal would be implemented. The long-term effectiveness would be ensured through the annual implementation of LUCs in the form of public education of any potential remaining hazards on-site and the installation and maintenance of warning signs. Five-Year Reviews would be conducted to ensure that the LUCs remain protective of potential human receptors.

11.3.4.2.2 Alternative 4 would result in complete removal of MEC in the "focused" surface and subsurface area of the MRS as defined in **Table 10.3**. Alternative 4 includes the intentional removal and/or treatment of MEC (demolition), thus satisfying the statutory preference for employing treatment as a principal element.

11.3.4.2.3 Implementation of Alternative 4 would result in short-term hazards to workers involved with the surface and subsurface MEC removal activities because of the increased likelihood of MEC exposure. Evacuation of non-essential personnel would be necessary for some locations during MEC removal. However, these hazards would be managed using industry standard safety procedures (e.g., using qualified UXO personnel, enforcement of safe separation distances, engineering controls, etc.), which would also minimize any associated potential risks to the surrounding community. Alternative 4 would not cause minimal short-term effects on the environment. This alternative would require vegetation clearing due to the low ground clearance (typically 6 inches) required for the DGM/AGC equipment that would be used. Soil disturbance would occur where TOI are investigated by manual excavation. After removal of MEC from the excavation location, the native soil will be replaced and the area restored, as appropriate. The estimated timeframe for implementing the removal action portion of Alternative 4 is 12 weeks.

11.3.4.2.4 All technologies and methods involved in implementing Alternative 4 are well established and would be technically and administratively implementable. The services and materials required to implement the work are readily available: (1) DGM instruments such as the EM-61 or equivalent are standard for this type of work and easily obtainable; (2) AGC instruments such as the man portable vector (MPV), UltraTEM, or equivalent are standard for this type of work and a DoD Advanced Geophysical Classification Accreditation

Program (DAGCAP)-certified contractor would be used; (3) Similarly, handheld analog detectors can easily be obtained to support the MEC removal effort; and (4) UXO-qualified personnel who are specially trained for EOD work and who would support the DGM/AGC and conduct any MEC removal would be readily available. Conversely, Alternative 4 is dependent on landowner participation, ROEs must be granted or renewed for the work to occur; however, the entire 25-acre "focused" area is within the jurisdiction of the Park. Equipment and personnel required to complete Alternative 4 are readily available.

11.3.4.2.5 The TPV cost of implementing Alternative 4 at the NDNODS Fort Tuthill Small Arms Range North MRS is estimated as $1,847,912 (**Table J.4** and **Appendix J**). As Alternative 4 does not achieve UU/UE, Five-Year Reviews would be required. Cost for five-year reviews is not included.

11.3.5 ALTERNATIVE 5 – COMPLETE SURFACE AND SUBSURFACE MEC REMOVAL (UU/UE)

A description of this alternative is provided in **Subchapter 10.3.5**.

11.3.5.1 ASSESSMENT OF THRESHOLD CRITERIA

11.3.5.1.1 The remedial actions associated with Alternative 5 would serve to eliminate human interaction with MEC by removing all surface and subsurface MEC throughout the NDNODS Fort Tuthill Small Arms Range North MRS. Alternative 5 would attain UU/UE and would be protective of receptors to the maximum depth of anticipated munitions such that there are no unacceptable risks resulting from exposure to MEC. This alternative is protective of human health and the environment and meets the criterion. The risk for the MEC contaminated area would be revised to "acceptable", after implementation of this alternative (**Appendix I**).

11.3.5.1.2 Investigation-derived waste material produced would be subject to the action-specific ARAR, RCRA (Subpart X). All materials resulting from MEC disposal activities would be inspected, certified as MDAS, transported under chain of custody control, and disposed by smelting.

11.3.5.2 ASSESSMENT OF BALANCING CRITERIA

11.3.5.2.1 Successful implementation of the remedial actions under Alternative 5 would be effective at reducing risk over the long-term through removal of all surface and subsurface MEC. The depth of MEC at the MRS is presented in **Table 10.4**. Implementing Alternative 5 may result in some MEC remaining in areas where ROE is refused. The depths that MEC is detected and removed and whether 100% coverage was attained will be evaluated post-removal to verify that UU/UE is achieved. In the event that UU/UE is not achieved LUCs as described in Alternative 2 would be implemented. In that case, the long-term effectiveness would be ensured through the annual implementation of LUCs in the form of public education of any potential remaining hazards on-site and the installation and maintenance of warning signs. Five-Year Reviews would be conducted to ensure that the LUCs remain protective of potential human receptors.

11.3.5.2.2 Alternative 5 would result in complete removal of MEC in the surface and subsurface of the MRS as defined in **Table 10.4**. Alternative 5 includes the intentional removal and/or treatment of MEC (demolition), thus satisfying the statutory preference for employing treatment as a principal element.

11.3.5.2.3 Implementation of Alternative 5 would result in short-term hazards to workers involved with the surface and subsurface MEC removal activities because of the increased likelihood of MEC exposure. Evacuation of non-essential personnel would be necessary for some locations during MEC removal. However, these hazards would be managed using industry standard safety procedures (e.g., using qualified UXO personnel, enforcement of safe separation distances, engineering controls, etc.), which would also minimize any associated potential risks to the surrounding community. Alternative 5 would not cause minimal short-term effects on the environment. This alternative would require vegetation clearing due to the low ground clearance (typically 6 inches) required for the DGM/AGC equipment that would be used. Soil disturbance would occur where TOI are investigated by manual excavation. After removal of MEC from the excavation location, the native soil will be replaced and the area restored, as appropriate. The estimated timeframe for implementing the removal action portion of Alternative 5 is 14 weeks.

11.3.5.2.4 All technologies and methods involved in implementing Alternative 5 are well established and would be technically and administratively implementable. The services and materials required to implement

the work are readily available: (1) DGM instruments such as the EM-61 or equivalent are standard for this type of work and easily obtainable; (2) AGC instruments such as the man portable vector (MPV), UltraTEM, or equivalent are standard for this type of work and a DoD Advanced Geophysical Classification Accreditation Program (DAGCAP)-certified contractor would be used; (3) Similarly, handheld analog detectors can easily be obtained to support the MEC removal effort; and (4) UXO-qualified personnel who are specially trained for EOD work and who would support the DGM/AGC and conduct any MEC removal would be readily available. Conversely, Alternative 5 is dependent on landowner participation, ROEs must be granted or renewed for the work to occur. Although equipment and personnel required to complete Alternative 5 are readily available, if implementation of the alternatives throughout the MRS is limited by ROE, the overall effectiveness would decrease.

11.3.5.2.5 The TPV cost of implementing Alternative 5 at the NDNODS Fort Tuthill Small Arms Range North MRS is estimated as $4,984,654 (**Table J.5** and **Appendix J**). In the event that Alternative 5 does not achieve UU/UE, Five-Year Reviews would be required. Cost for five-year reviews is not included.

11.4 FIVE-YEAR REVIEWS

While not a specific component of the remedies described in the previous subchapters, five-year reviews would also be required for any remedial alternative under which hazardous substances, pollutants or contaminants remain above levels allowing UU/UE following remedy implementation. These reviews, as outlined in Section 121 of CERCLA, as amended by the Superfund Amendments and Reauthorization Act, and Section 300.430(f)(ii) of the NCP, are conducted to determine if the remedial alternative continues to minimize human health risks and continues to be protective of human health, safety, and the environment. Five-year reviews would be required for Alternatives 2, 3, and 4 and are included in the cost estimates discussed in **Appendix J** and summarized in **Table J.1**.

11.5 COMPARATIVE ANALYSIS OF ALTERNATIVES

The detailed analysis performed in **Section 11.3** discussed the degree of compliance to the evaluation criteria for each remedial alternative. This section provides a comparative analysis of each remedial alternative (in relation to one another) with respect to each of the NCP evaluation criteria (**Subchapter 11.2**). The purpose of this evaluation is to identify the relative advantages and disadvantages of each alternative. **Table J.1** summarizes the alternative costs by their component elements. **Table 11.1** summarizes the results of the comparative analysis.

11.5.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Remedial Alternatives 4 and 5 would all be protective of human health and the environment by addressing the exposure of receptors to MEC such that there are no unacceptable risks remaining at the NDNODS Fort Tuthill Small Arms Range North MRS. Remedial Alternatives 2 and 3 would be protective of human health and the environment by addressing the exposure of receptors to MEC such that there are no unacceptable risks remaining at the “Remainder of MRS” area only, not in the “Focused Area”. Alternative 1 (No Action), which does not include any remedial technologies is only included in the FS to provide a baseline for comparison. Remedial alternatives are either protective or not and, therefore, no comparison of overall protectiveness is possible between alternatives.

11.5.2 COMPLIANCE WITH ARARS

All remedial alternatives identified to address MEC risk at the NDNODS Fort Tuthill Small Arms Range North MRS comply with ARARs where applicable. There are no chemical-specific, location-specific, or action-specific ARARs identified for alternatives 1 and 2. Alternatives 3, 4, and 5 will include MEC disposal if MEC is encountered and will comply with RCRA Subpart X. No other ARARs have been identified.

11.5.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

No actions would be taken under Alternative 1 to address the explosive hazards associated with residual surface and subsurface MEC at the MRS. Alternative 1 would not provide long-term effectiveness and permanence. Notably, there are different degrees of long-term effectiveness and permanence associated with Alternatives 2, 3, 4, and 5. Alternatives 3 through 5 are more effective over the long-term and more permanent than Alternative 2 because they involve some measure of MEC removal. Of the alternatives, Alternative 5 is the most effective because the MEC removal is complete resulting in UU/UE.

11.5.4 REDUCTION OF TMV THROUGH TREATMENT

Alternative 1 takes no actions, it does not provide any reduction of the toxicity, mobility, or volume of MEC. Alternative 2 does not implement any treatment technologies, therefore does not provide any reduction of the toxicity, mobility, or volume of MEC. Alternatives 3 through 5 achieve reduction in TMV of wastes because they all involve some measure of MEC removal/disposal. Of these alternatives, Alternative 5 achieves the greatest reduction in TMV of wastes because the associated MEC removal/disposal includes both surface and subsurface MEC across the entire site. The MEC removal associated with Alternative 3 only focuses on potential MEC located on the surface; therefore, the reduction achieved with Alternative 3 is not as great as with Alternative 4 or 5. The MEC removal associated with Alternative 4 only focuses on potential MEC located in a portion of the MRS; therefore, the reduction achieved with Alternatives 4 is not as great as with Alternative 5.

11.5.5 SHORT-TERM EFFECTIVENESS

Alternative 1 would take no action and there are no adverse short-term effects, additionally Alternative 1 would not take any time to implement. Implementation of Alternatives 2 through 5 would result in short-term hazards to workers involved with the MEC removal activities or the installation of warning signs because of the increased likelihood of MEC exposure. Of Alternatives 2, 3, 4, and 5, Alternatives 3 through 5 would present the greatest short-term hazards to workers because the associated MEC removal actions. In all cases, hazards to workers during implementation of the alternatives would be managed using industry standard safety procedures (e.g., using qualified UXO personnel, enforcement of safe separation distances, engineering controls, etc.), which would also minimize any associated potential risks to the surrounding community. Alternatives 2 through 5 would not cause any adverse short-term effects on the environment. The estimated timeframe for implementing the remedial actions of Alternative 2 is 1 week, Alternative 3 is 8 weeks, Alternative 4 is 12 weeks, and Alternative 5 is 14 weeks. Maintenance of warning signs and distribution of public educational materials will continue to be implemented annually.

11.5.6 IMPLEMENTABILITY

There are no implementability limitations associated with Alternative 1. Alternatives 2, 3, 4, and 5 are all technically and administratively feasible but require (1) specialized personnel and equipment to implement MEC removal and (2) the development of detailed work plans. Additionally, ROE is required to perform any remedial action and implementation of these alternatives is dependent on landowner participation.

11.5.7 COST

Since no action would be implemented under Alternative 1, there are no costs associated with this alternative. The TPV of implementing Alternative 2 would be $507,195. The TPV of implementing Alternative 3 would be $1,830,128. The TPV of implementing Alternative 4 would be $1,847,912. The TPV of implementing Alternative 5 would be $4,984,654. Alternative 5 has the highest costs. Alternative 5 is more expensive than Alternatives 3 and 4 because it requires a complete removal of potential MEC, both surface and subsurface, while Alternative 3 only involves a surface MEC removal and Alternative 4 only involves a portion of the MRS. Alternative 2 is the least expensive of the remedial alternatives as it does not involve a MEC removal action, only LUCs. Both Alternatives 2 and 3 would require follow-on costs (i.e., O&M, periodic, or Five-Year Reviews). **Tables J.1-J.5** summarize costs for each alternative, and **Appendix J** provides additional cost information.

11.5.8 STATE ACCEPTANCE

Arizona State acceptance cannot be evaluated and assessed until comments on the FS and PP are received.

11.5.9 COMMUNITY ACCEPTANCE

Community acceptance cannot be evaluated fully until input is received on the FS (this document) and a PP is prepared and submitted for public comment.

11.6 CONCLUSIONS

The remedial alternatives identified to address MEC risk at the NDNODS Fort Tuthill Small Arms Range North MRS were evaluated against the NCP evaluation criteria. The comparative analysis of alternatives was conducted using the current CSM for the NDNODS Fort Tuthill Small Arms Range North MRS, which is based on the present state of knowledge concerning contamination and both current and reasonably anticipated future land use. This FS evaluates various alternatives but does not select an alternative for future response actions. The selection of an alternative must be made by the stakeholders following review of this FS. The preferred alternative will be identified in a subsequent document, the PP, which will be prepared and submitted separately for public comment. A DD will then be issued to present the selected remedy for the NDNODS Fort Tuthill Small Arms Range North MRS.

Table 11.1 Comparison of Alternatives

CERCLA Evaluation Criteria	Alternative 1 No Action	Alternative 2 LUCs	Alternative 3 Surface MEC Removal with LUCs	Alternative 4 Focused Surface and Subsurface MEC Removal and LUCS	Alternative 5 Complete Surface and Subsurface MEC Removal
Protective of Human Health and the Environment	No	Focused Area – No No change in Decision Logic to Assess Risk Remainder of MRS - Yes Change in Decision Logic to Assess Risk (Unacceptable to Acceptable)	Focused Area – No Not protective of human health because does not decrease amount of MEC in subsurface and future intrusive plans for the area. Yes Change in Decision Logic to Assess Risk (Unacceptable to Acceptable)	Yes Change in Decision Logic to Assess Risk (Unacceptable to Acceptable	Yes Change in Decision Logic to Assess Risk (Unacceptable to Acceptable)
Complies with Applicable or Relevant and Appropriate Requirements	Yes	Yes	Yes	Yes	Yes
Effective and Permanent	No	Medium	High	High	Highest
Reduces Toxicity, Mobility, or Volume through Treatment	None (no treatment)	None (no treatment)	Reduction in volume of MEC on ground surface	Reduction in volume of MEC on ground surface and in subsurface in 25-acre “focused” area	Reduction in volume of MEC on ground surface and in subsurface
Short-Term Effectiveness	No short-term hazards to workers and surrounding area	Some short-term hazards to workers and surrounding area	Significant short-term hazards to workers and surrounding area	Greatest short-term hazards to workers and surrounding area	Greatest short-term hazards to workers and surrounding area
Implementable	Readily Implementable	Readily Implementable	Readily Implementable	Readily Implementable	Readily Implementable
State Acceptance		To be determined during preparation of the Proposed Plan and Decision Document			
Community Acceptance		To be determined during preparation of the Proposed Plan and Decision Document			
Cost (1)	$0	$507,195	$1,830,128	$1,847,912	$4,984,654

(1) Costs shown are based on alternative implementation duration estimates with recurring costs based on 30-year planning horizons specified in the RI/FS Guidance (USEPA, 1988) for the purposes of evaluating and comparing alternatives with a 20% contingency reported as a TPV. The TPV is based on a discount rate of 7 percent. Details of the cost estimates and the development of the TPVs are provided in Appendix J.

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Appendix I
Risk Management Methodology
Alternatives Matrices

The Risk Management Methodology (RMM) Matrices for the Fort Tuthill Small Arms Range North MRS.

Table I.1 Risk Management Methodology: Alternative 2, Public Education and Warning Signs (LUCs), Fort Tuthill Small Arms Range North MRS

Matrix 1: Likelihood of Encounter

Likelihood of Encounter (*Amount of MEC versus Access Conditions*)		Access Conditions (frequency of use)			
		Regular	Often	Intermittent	Rare
Amount of MEC	**Category I (Most)**	Frequent	Frequent	Likely	Occasional
	Category II	Frequent	Likely	Occasional	Seldom
	Category III	Likely	Occasional	Seldom	Unlikely
	Category IV	Occasional	Seldom	Unlikely	Unlikely
	Category V	Seldom	Seldom	Unlikely	Unlikely
	Category VI (Least)	Unlikely	Unlikely	Unlikely	Unlikely

Rationale*: Implementing LUCs as described would not change the amount of MEC or the access conditions.*

Focused Area Baseline Conditions:
Remainder of MRS Baseline Conditions:
Focused Area Conditions After Remedial Response:
Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Matrix 2: Severity of Incident

Severity of Explosive Incident (*Severity vs. Likelihood of Encounter*)		Likelihood of Encounter (from Matrix 1)				
		Frequent	Likely	Occasional	Seldom	Unlikely
Severity	**Catastrophic/Critical**	A	A	B	B	D
	Modest	B	B	B	C	D
	Minor	B	C	C	C	D
	Improbable	D	D	D	D	D

Rationale*: Implementing LUCs as described would not change the severity of an unplanned detonation.*

Focused Area Baseline Conditions:
Remainder of MRS Baseline Conditions:
Focused Area Conditions After Remedial Response:
Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Matrix 3: Likelihood of Detonation

Likelihood of Detonation (*Sensitivity vs. Likelihood to Impart Energy*)		Likelihood to Impart Energy on an Item		
		High	Modest	Inconsequential
Sensitivity	**High**	1	1	3
	Moderate	1	2	3
	Low	1	3	3
	Not Sensitive	2	3	3

Rationale*: Implementing LUCs as described would affect human behavior, decreasing the likelihood to impart energy on an item.*

Focused Area and Remainder of MRS Baseline Conditions:
Focused Area and Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Matrix 4: Acceptable and Unacceptable Site Conditions

	Acceptable and Unacceptable Site Conditions	Result from Matrix 2			
		A	B	C	D
Result from Matrix 3	1	**Unacceptable**	**Unacceptable**	**Unacceptable**	Acceptable
	2	**Unacceptable**	**Unacceptable**	Acceptable	Acceptable
	3	**Unacceptable**	Acceptable	Acceptable	Acceptable

CONCLUSION: *Implementing Alternative 2 would change the site risk conditions from the baseline under current and anticipated future conditions for the Remainder of MRS. Implementing Alternative 2 in the Focused Area would not change site risk conditions.*

Focused Area Baseline Conditions:
Remainder of MRS Baseline Conditions:

Focused Area Conditions After Remedial Response:
Remainder of MRS Conditions After Remedial Response:

Result of Implementing Remedial Alternative

Table I.2 Risk Management Methodology: Alternative 3, Complete Surface MEC Removal and LUCs, Fort Tuthill Small Arms Range North MRS

Matrix 1: Likelihood of Encounter

Likelihood of Encounter (*Amount of MEC versus Access Conditions*)		Access Conditions (frequency of use)			
		Regular	Often	Intermittent	Rare
Amount of MEC	**Category I (Most)**	Frequent	Frequent	Likely	Occasional
	Category II	Frequent	Likely	Occasional	Seldom
	Category III	**Likely**	Occasional	Seldom	Unlikely
	Category IV	**Occasional**	Seldom	Unlikely	Unlikely
	Category V	**Seldom**	Seldom	Unlikely	Unlikely
	Category VI (Least)	Unlikely	Unlikely	Unlikely	Unlikely

Rationale: *The surface MEC removal would reduce the amount of MEC via source removal.*

Focused Area Baseline Conditions:
Remainder of MRS Baseline Conditions:
Focused Area Conditions After Remedial Response:
Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Matrix 2: Severity of Incident

Severity of Explosive Incident (*Severity vs. Likelihood of Encounter*)		Likelihood of Encounter (from Matrix 1)				
		Frequent	Likely	Occasional	Seldom	Unlikely
Severity	**Catastrophic/Critical**	A	A	B	B	D
	Modest	B	B	B	C	D
	Minor	B	C	C	C	D
	Improbable	D	D	D	D	D

Rationale: *The surface MEC removal would not change the severity of an unplanned detonation.*

Focused Area Baseline Conditions:
Remainder of MRS Baseline Conditions:
Focused Area Conditions After Remedial Response:
Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Matrix 3: Likelihood of Detonation

Likelihood of Detonation (*Sensitivity vs. Likelihood to Impart Energy*)		Likelihood to Impart Energy on an Item		
		High	Modest	Inconsequential
Sensitivity	**High**	1	1	3
	Moderate	1	2	3
	Low	1	3	3
	Not Sensitive	2	3	3

Rationale: *Implementing LUCs as described would affect human behavior, decreasing the likelihood to impart energy on an item.*

Focused Area and Remainder of MRS Baseline Conditions:
Focused Area and Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Matrix 4: Acceptable and Unacceptable Site Conditions

	Acceptable and Unacceptable Site Conditions	Result from Matrix 2			
		A	B	C	D
Result from Matrix 3	1	**Unacceptable**	**Unacceptable**	**Unacceptable**	Acceptable
	2	**Unacceptable**	**Unacceptable**	Acceptable	Acceptable
	3	**Unacceptable**	Acceptable	Acceptable	Acceptable

CONCLUSION: *Implementing Alternative 3 would change the site risk conditions from the baseline under current and anticipated future conditions.*

Focused Area Baseline Conditions:
Remainder of MRS Baseline Conditions:

Focused Area Conditions After Remedial Response:
Remainder of MRS Conditions After Remedial Response:

Result of Implementing Remedial Alternative

Table I.3 Risk Management Methodology: Alternative 4, Focused Surface and Subsurface MEC Removal and LUCs, Fort Tuthill Small Arms Range North MRS

Matrix 1: Likelihood of Encounter

Likelihood of Encounter (*Amount of MEC versus Access Conditions*)		Access Conditions (frequency of use)			
		Regular	Often	Intermittent	Rare
Amount of MEC	**Category I (Most)**	Frequent	Frequent	Likely	Occasional
	Category II	Frequent	Likely	Occasional	Seldom
	Category III	**Likely**	Occasional	Seldom	Unlikely
	Category IV	Occasional	Seldom	Unlikely	Unlikely
	Category V	**Seldom**	Seldom	Unlikely	Unlikely
	Category VI (Least)	**Unlikely**	Unlikely	Unlikely	Unlikely

Rationale: *The complete surface and subsurface MEC removal in the Focused Area would reduce the amount of MEC to Category VI via source removal.*

Focused Area Baseline Conditions:
Remainder of MRS Baseline Conditions:
Focused Area Conditions After Remedial Response:
Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Matrix 2: Severity of Incident

Severity of Explosive Incident (*Severity vs. Likelihood of Encounter*)		Likelihood of Encounter (from Matrix 1)				
		Frequent	Likely	Occasional	Seldom	Unlikely
Severity	**Catastrophic/Critical**	A	**A**	B	**B**	**D**
	Modest	B	B	B	C	D
	Minor	B	C	C	C	D
	Improbable	D	D	D	D	D

Rationale: *The surface and subsurface MEC removal would not change the severity of an unplanned detonation.*

Focused Area Baseline Conditions:
Remainder of MRS Baseline Conditions:
Focused Area Conditions After Remedial Response:
Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Matrix 3: Likelihood of Detonation

Likelihood of Detonation (*Sensitivity vs. Likelihood to Impart Energy*)		Likelihood to Impart Energy on an Item		
		High	Modest	Inconsequential
Sensitivity	**High**	1	1	3
	Moderate	1	2	3
	Low	1	3	3
	Not Sensitive	2	3	3

Rationale: *Implementing LUCs as described would affect human behavior, decreasing the likelihood to impart energy on an item.*

Focused Area and Remainder of MRS Baseline Conditions:
Focused Area and Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Matrix 4: Acceptable and Unacceptable Site Conditions

	Acceptable and Unacceptable Site Conditions	Result from Matrix 2			
		A	B	C	D
Result from Matrix 3	1	**Unacceptable**	**Unacceptable**	**Unacceptable**	Acceptable
	2	**Unacceptable**	**Unacceptable**	Acceptable	Acceptable
	3	**Unacceptable**	**Acceptable**	Acceptable	**Acceptable**

CONCLUSION: *Implementing Alternative 4 would change the site risk conditions from the baseline under current and anticipated future conditions.*

Focused Area Baseline Conditions:
Remainder of MRS Baseline Conditions:
Focused Area Conditions After Remedial Response:
Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Table I.4 Risk Management Methodology: Alternative 5, Complete Surface and Subsurface MEC Removal (UU/UE), Fort Tuthill Small Arms Range North MRS

Matrix 1: Likelihood of Encounter

Likelihood of Encounter (*Amount of MEC versus Access Conditions*)		Access Conditions (frequency of use)			
		Regular	Often	Intermittent	Rare
Amount of MEC	**Category I (Most)**	Frequent	Frequent	Likely	Occasional
	Category II	Frequent	Likely	Occasional	Seldom
	Category III	**Likely**	Occasional	Seldom	Unlikely
	Category IV	Occasional	Seldom	Unlikely	Unlikely
	Category V	**Seldom**	Seldom	Unlikely	Unlikely
	Category VI (Least)	**Unlikely**	Unlikely	Unlikely	Unlikely

Rationale: *The complete surface and subsurface MEC removal would reduce the amount of MEC to Category VI (Least) via source removal.*

Focused Area Baseline Conditions:
Remainder of MRS Baseline Conditions:
Focused Area Conditions After Remedial Response:
Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Matrix 2: Severity of Incident

Severity of Explosive Incident (*Severity vs. Likelihood of Encounter*)		Likelihood of Encounter (from Matrix 1)				
		Frequent	Likely	Occasional	Seldom	Unlikely
Severity	**Catastrophic/Critical**	A	**A**	B	**B**	**D**
	Modest	B	B	B	C	D
	Minor	B	C	C	C	D
	Improbable	D	D	D	D	D

Rationale: *The surface and subsurface MEC removal would not change the severity of an unplanned detonation.*

Focused Area Baseline Conditions:
Remainder of MRS Baseline Conditions:
Focused Area Conditions After Remedial Response:
Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Matrix 3: Likelihood of Detonation

Likelihood of Detonation (*Sensitivity vs. Likelihood to Impart Energy*)		Likelihood to Impart Energy on an Item		
		High	Modest	Inconsequential
Sensitivity	**High**	1	**1**	**3**
	Moderate	1	2	3
	Low	1	3	3
	Not Sensitive	2	3	3

Rationale: *The surface and subsurface MEC removal would decrease the likelihood of detonation.*

Focused Area and Remainder of MRS Baseline Conditions:
Focused Area and Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Matrix 4: Acceptable and Unacceptable Site Conditions

Result from Matrix 3	Acceptable and Unacceptable Site Conditions	Result from Matrix 2: A	B	C	D
	1	**Unacceptable**	**Unacceptable**	**Unacceptable**	
	2	**Unacceptable**	**Unacceptable**	Acceptable	Acceptable
	3	**Unacceptable**	Acceptable	Acceptable	**Acceptable**

CONCLUSION: *Implementing Alternative 4 would change the site risk conditions from the baseline under current and anticipated future conditions.*

Focused Area Baseline Conditions:
Remainder of MRS Baseline Conditions:
Focused Area Conditions After Remedial Response:
Remainder of MRS Conditions After Remedial Response:
Result of Implementing Remedial Alternative

Appendix J
Cost Backup

J.1 OVERVIEW

J.1.1 INTRODUCTION

This appendix presents the assumptions used to calculate the costs for the various remedial alternatives presented in the FS for MEC. Each set of alternatives comprises one or more discrete components (e.g., land use controls, MEC removal, soil excavation, etc.). The costs for each component are totaled to provide the overall cost for the alternative. For this reason, the cost assumptions are presented for each component rather than by remedial alternative. The cost breakdown for each remedial alternative are presented in **Table J.1.**

J.1.2 GENERAL COST ASSUMPTIONS

J.1.2.1 The total costs for each for each remedial alternative include direct, indirect, and long-term O&M costs. Direct costs are those costs associated with the implementation of the alternative. Indirect costs are those costs associated with administration, oversight, and contingencies. For periodic costs, such as five-year reviews and O&M, the estimate is based on a project life of 30 years for consistency and comparability as well as in accordance with EPA guidance. Cost estimates presented are order-of-magnitude level estimates based on a variety of information including productivity estimates (based on MRS conditions), cost estimating guides, and prior experience at the MRS. The actual costs will depend on true labor rates, actual weather conditions, final project scope, and other variable factors fully developed during pre-design.

J.1.2.2 In accordance with USEPA guidance, a present value analysis is conducted to evaluate costs (capital and O&M) that occur over different periods. The TPV is the amount needed to be set aside at the initial point in time (the “base year,” or “Year 0”) to ensure funds will be available in the future as they are needed. A discount rate of 7 percent was used to estimate TPV per the USEPA guidance, A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, (USEPA, 2000). It should be noted that while USEPA suggests the TPV be presented in the FS, USACE projects are not typically funded in this way. For this reason, the total non-discounted constant dollar cost provides a better indication of the total cost to USACE.

J.1.2.3 Also in accordance with USEPA (2000) guidance, a contingency cost is factored into the cost estimate to address unknowns, unforeseen circumstances, or unanticipated conditions. For the purposes of the FS, the contingency is applied as a percentage of the total cost of construction or O&M activities costs, rather than being applied to individual cost elements. Scope contingency is included to cover unknown costs due to scope changes that may occur during design, and typically ranges from 10 to 25 percent. Bid contingency rep-resents costs that are unforeseeable at the time of estimate preparation, which are likely to become known as the remedial action construction or O&M proceeds, and typically ranges from 10 to 20 percent. For this FS cost estimate, scope and bid contingency costs were each estimated to be 10 percent for a total overall contingency of 20 percent.

J.1.2.4 Remedial action alternative cost estimates for the detailed analysis are intended to provide a measure of total resource costs over time (i.e., “life cycle costs”) associated with any given alternative. As such, these estimates generally are based on more detailed information and should achieve a greater level of accuracy than screening-level estimates. The detailed analysis level accuracy range of –30 to +50 percent means that, for an estimate of $100,000, the actual cost of an alternative is expected to be between $70,000 and $150,000 (USEPA, 2000).

J.2 COST ESTIMATE ASSUMPTIONS FOR ALTERNATIVE COMPONENTS

J.2.1 COMPONENTS OF MUNITIONS AND EXPLOSIVES OF CONCERN ALTERNATIVES

The cost assumptions for the various components of each remedial alternative for MEC are presented below. The costs for all components assume ROE has been granted for 100% of the MRS acreage (exception for Alternative 4). **Table J.1** includes the cost summaries for the remedial alternatives.

J.2.1.1 PLANNING, REPORTING, AND MEETINGS

This component includes the costs for implementing the systematic project planning (SPP) process, development of a Project Management Plan/Quality Assurance Surveillance Plan, Remedial Action Work Plan (including all supporting plans), Site-Specific Final Report, and After-Action Report (for MEC). For SPP, three meetings are assumed coupled with Public Meetings same day and include associated costs for travel to Flagstaff. These costs are capital costs that are assumed to occur in the base year (Year 0). This component does not include the costs for five-year reviews, which are addressed separately (see below).

J.2.1.2 IMPLEMENTATION OF LAND USE CONTROLS

This component includes the base year (Year 0) costs for installation of warning signs at park access points (e.g., park entrance, visitor center, kiosks) along with the production and distribution of educational materials.

J.2.1.3 MAINTENANCE OF LAND USE CONTROLS

This component includes the costs for purchase and replacement of 5 warning signs per year (roughly 20%) along with the yearly production and distribution of educational materials. In the base year – Year 0, costs include the installation of warning signs at park access points.

J.2.1.4 VEGETATION REMOVAL

J.2.1.4.1 The costs for this component assume onsite personnel consist of UXO Safety, and one brush clearing team consisting of two UXO Technician II using mechanized equipment throughout the duration of vegetation removal.

J.2.1.4.2 Production estimate of 2.5 acres per day per team over 100 acres (brush clearing estimated to be necessary over 50% of the removal area) based on the known light understory vegetation and gentle terrain throughout most of the MRS. Prorated for Alternative 4 for effective 25-acre “focused” area. Costs are based on a 1-month duration estimate and include vegetation clearance team costs and duration-based supervisory costs, labor, airfare/travel, and per diem. Additional costs include rental vehicles, equipment, shipping, sanitation, communications, and other associated field purchases and equipment rentals.

J.2.1.5 SURFACE MEC REMOVAL

J.2.1.5.1 The costs for this component assume an instrument-aided visual surface removal of MEC over the entire 100-acre MRS. Prorated for Alternative 4 for effective 25-acre “focused” area. Production estimated based on adjusted actual average production for similar sites, working 10-hour days and 5-day weeks.

J.2.1.5.2 Although there were no MEC recovered during the RI their potential presence cannot be ruled out. If surface MEC is recovered, each item will be photographed and cataloged and consolidated or BIP. Demolition shots are assumed to occur once during the surface MEC removal.

J.2.1.5.3 Costs are based on an estimated 6-week surface clearance effort. Surface MEC clearance estimate is based upon a clearance rate of 2 acres per day per team and utilizing 2 teams, each consisting of 1 UXO Technician III (Team Lead) and 4 UXO Technicians II. A Senior UXO Supervisor (SUXOS)/site manager and a UXO Quality Control Specialist (UXOQCS)/UXO Safety Officer (UXOSO) will be maintained for the duration of field operations. A 20% overlap is assumed for the brush clearing and surface MEC removal operations to give an overall duration of 8 weeks.

J.2.1.5.4 Costs are duration-based and include supervisory costs, labor, airfare/travel, and per diem. Additional costs include rental vehicles, equipment, shipping, sanitation, communications, and other associated field purchases and equipment rentals. Disposal costs for storage and disposal of MD are included as well as demolition costs for consolidated shot/BIP procedures.

J.2.1.6 COMPLETE SURFACE AND SUBSURFACE MEC REMOVAL

J.2.1.6.1 The costs for this component assume DGM/AGC mapping and intrusive investigation of all TOIs over the entire 100-acre MRS. Prorated for Alternative 4 for effective 25-acre "focused" area. The costs for this component assume onsite personnel consist of a site management team of a Site Manager, UXOSO, and UXOQCS. A SUXOS will be present during intrusive operations. Dynamic DGM will be conducted by two teams consisting of an instrument operator with a UXO Technician II escort. Cued surveys with an advanced geophysical sensor will be conducted by two teams of one operator and one UXO Technician II. Intrusive investigation of anomalies will be conducted by two teams, each led by a UXO Technician III and including two UXO Technicians II. Production estimated based on adjusted actual average production for similar sites, working 10-hour days and 5-day weeks. A 20% overlap is assumed for the brush clearing and MEC removal operations to give an overall duration of 14 weeks.

J.2.1.6.2 Although there were no MEC recovered during the RI their potential presence cannot be ruled out. If surface MEC is recovered, each item will be photographed and cataloged and consolidated or BIP. Demolition shots are assumed to occur once during the subsurface MEC removal.

J.2.1.6.3 Costs based on 4 weeks of brush clearing, a 28-week DGM survey, a 22-week AGC survey, and 7 weeks of intrusive investigation. Duration estimate is based on a DGM survey production rate of 0.4 acres per day per team utilizing 2 teams, each consisting of 1 instrument operator and 1 UXO Technician II escort. DGM processing is assumed to require 40 hrs per field team week. The AGC cued survey estimate is based on a production rate of 185 anomalies per team per day (39,820 estimated anomalies of interest based upon RI data) utilizing 2 teams, each consisting of 1 instrument operator and 1 UXO Technician II escort. Intrusive investigation is based on a production rate of 80 anomalies per team per day (resulting in an estimated 5,973 TOIs based upon data from similar sites; based on an 85% reduction), utilizing 2 teams consisting of 1 UXO Technician III (Team Lead) and 4 UXO Technicians II. Based on the RI data, the average anomaly density is estimated to be 362 anomalies per acre which for 100 acres yields 39,820 anomalies.

J.2.1.6.4 Costs are duration-based and include supervisory costs, labor, airfare/travel, and per diem. Costs include a DGM survey followed by an AGC survey to identify anomalies for removal. Additional costs include rental vehicles, equipment, shipping, sanitation, communications, and other associated field purchases and equipment rentals. Disposal costs for storage and disposal of MD are included as well as demolition costs for BIP procedures.

J.2.1.7 FIVE-YEAR REVIEW

The costs for this component assume recurring five-year reviews conducted over a 30-year period (a total of six reviews: Years 5, 10, 15, 20, 25, and 30). Individual reviews are estimated to cost $88,037. The costs of five-year reviews are included in the Alternative cost estimates.

Table J.1 Cost Summary of Remedial Alternatives

Remedial Components		Costs (1)			
		Alternative 2	Alternative 3	Alternative 4	Alternative 5
Capital (Year 0) Costs	Planning, Reporting, Meetings	$0	$108,076	$108,076	$108,076
	LUCs (Warning Signs, Educational Materials)	$32,760	$32,760	$32,760	$0
	Surface MEC Removal	$0	$994,368	0	$0
	Partial Surface and Subsurface MEC Removal (25-acres) with LUCs	$0	$0	$1,009,188	$0
	Complete Surface and Subsurface MEC Removal	$0	$0	$0	$4,045,802
Year 0 Cost (2)		**$32,760**	**$1,135,204**	**$1,150,024**	**$4,153,878**
Year 0 Cost, plus 20% Contingency		**$39,212**	**$1,362,245**	**$1,380,029**	**$4,984,654**
Periodic Costs	Five-year Reviews	$528,224	$528,224	$528,224	$0
	LUCs (Sign Replacement, Educational Pamphlets) - Annual	$439,049	$439,049	$439,049	$0
Total 30-Year Cost – "Constant Dollars"		**$1,044,336**	**$2,146,780**	**$2,161,600**	**$4,153,878**
Total 30-Year Cost, plus 20% Contingency – TPV (3)		**$1,253,203**	**$2,576,136**	**$2,593,920**	**$4,984,654**

(1) Unless otherwise noted, costs are estimated in non-discounted "constant dollars" which are not affected by general price inflation.
(2) Includes capital costs of remedial action but excludes long-term monitoring and maintenance.
(3) Total Present Value (TPV) costs are based on a 7 percent discount rate.

Table J.2 Alternative 2. Calculations of Total Present Value (Lower and Upper Ranges)

Year	Capital Cost ($)	Annual Cost ($)	Periodic Cost ($) (5-Year Review)	Total Cost + 0% Tax ($)	Discount Factor at 7%	Present Value at 7%
0	$32,760			$32,760	1.000	$32,760
1		$16,112		$16,112	0.935	$15,058
2		$16,112		$16,112	0.873	$14,073
3		$16,112		$16,112	0.816	$13,152
4		$16,112		$16,112	0.763	$12,292
5		$16,112	$88,037	$104,149	0.713	$74,257
6		$16,112		$16,112	0.666	$10,736
7		$16,112		$16,112	0.623	$10,034
8		$16,112		$16,112	0.582	$9,377
9		$16,112		$16,112	0.544	$8,764
10		$16,112	$88,037	$104,149	0.508	$52,944
11		$16,112		$16,112	0.475	$7,655
12		$16,112		$16,112	0.444	$7,154
13		$16,112		$16,112	0.415	$6,686
14		$16,112		$16,112	0.388	$6,248
15		$16,112	$88,037	$104,149	0.362	$37,749
16		$16,112		$16,112	0.339	$5,458
17		$16,112		$16,112	0.317	$5,101
18		$16,112		$16,112	0.296	$4,767
19		$16,112		$16,112	0.277	$4,455
20		$16,112	$88,037	$104,149	0.258	$26,914
21		$16,112		$16,112	0.242	$3,891
22		$16,112		$16,112	0.226	$3,637
23		$16,112		$16,112	0.211	$3,399
24		$16,112		$16,112	0.197	$3,176
25		$16,112	$88,037	$104,149	0.184	$19,190
26		$16,112		$16,112	0.172	$2,774
27		$16,112		$16,112	0.161	$2,593
28		$16,112		$16,112	0.150	$2,423
29		$16,112		$16,112	0.141	$2,265
30		$16,112	$88,037	$104,149	0.131	$13,682
Total	$32,760	$483,352	$528,224	$1,044,336	**TPV**	**$422,662**
					TPV + 20% Contingency	**$507,195**
					Total Cost + 0% Tax ($)	**$1,044,336**
					Lower end of TPV Range at -30%	**$295,864**
					Upper end of TPV Range at +50%	**$633,993**

Table J.3 Alternative 3. Calculations of Total Present Value (Lower and Upper Ranges)

Year	Capital Cost ($)	Annual Cost ($)	Periodic Cost ($) (5-Year Review)	Total Cost + 0% Tax ($)	Discount Factor at 7%	Present Value at 7%
0	$1,135,204			$1,135,204	1.000	$1,135,204
1		$16,112		$16,112	0.935	$15,058
2		$16,112		$16,112	0.873	$14,073
3		$16,112		$16,112	0.816	$13,152
4		$16,112		$16,112	0.763	$12,292
5		$16,112	$88,037	$104,149	0.713	$74,257
6		$16,112		$16,112	0.666	$10,736
7		$16,112		$16,112	0.623	$10,034
8		$16,112		$16,112	0.582	$9,377
9		$16,112		$16,112	0.544	$8,764
10		$16,112	$88,037	$104,149	0.508	$52,944
11		$16,112		$16,112	0.475	$7,655
12		$16,112		$16,112	0.444	$7,154
13		$16,112		$16,112	0.415	$6,686
14		$16,112		$16,112	0.388	$6,248
15		$16,112	$88,037	$104,149	0.362	$37,749
16		$16,112		$16,112	0.339	$5,458
17		$16,112		$16,112	0.317	$5,101
18		$16,112		$16,112	0.296	$4,767
19		$16,112		$16,112	0.277	$4,455
20		$16,112	$88,037	$104,149	0.258	$26,914
21		$16,112		$16,112	0.242	$3,891
22		$16,112		$16,112	0.226	$3,637
23		$16,112		$16,112	0.211	$3,399
24		$16,112		$16,112	0.197	$3,176
25		$16,112	$88,037	$104,149	0.184	$19,190
26		$16,112		$16,112	0.172	$2,774
27		$16,112		$16,112	0.161	$2,593
28		$16,112		$16,112	0.150	$2,423
29		$16,112		$16,112	0.141	$2,265
30		$16,112	$88,037	$104,149	0.131	$13,682
Total	$1,135,204	$483,352	$528,224	$2,146,780	**TPV**	**$1,525,106**
					TPV + 20% Contingency	**$1,830,128**
					Total Cost + 0% Tax ($)	**$2,146,780**
					Lower end of TPV Range at -30%	**$1,067,574**
					Upper end of TPV Range at +50%	**$2,287,660**

Table J.4 Alternative 4. Calculations of Total Present Value (Lower and Upper Ranges)

Year	Capital Cost ($)	Annual Cost ($)	Periodic Cost ($) (5-Year Review)	Total Cost + 0% Tax ($)	Discount Factor at 7%	Present Value at 7%
0	$1,135,204			$1,150,024	1.000	$1,150,024
1		$16,112		$16,112	0.935	$15,058
2		$16,112		$16,112	0.873	$14,073
3		$16,112		$16,112	0.816	$13,152
4		$16,112		$16,112	0.763	$12,292
5		$16,112	$88,037	$104,149	0.713	$74,257
6		$16,112		$16,112	0.666	$10,736
7		$16,112		$16,112	0.623	$10,034
8		$16,112		$16,112	0.582	$9,377
9		$16,112		$16,112	0.544	$8,764
10		$16,112	$88,037	$104,149	0.508	$52,944
11		$16,112		$16,112	0.475	$7,655
12		$16,112		$16,112	0.444	$7,154
13		$16,112		$16,112	0.415	$6,686
14		$16,112		$16,112	0.388	$6,248
15		$16,112	$88,037	$104,149	0.362	$37,749
16		$16,112		$16,112	0.339	$5,458
17		$16,112		$16,112	0.317	$5,101
18		$16,112		$16,112	0.296	$4,767
19		$16,112		$16,112	0.277	$4,455
20		$16,112	$88,037	$104,149	0.258	$26,914
21		$16,112		$16,112	0.242	$3,891
22		$16,112		$16,112	0.226	$3,637
23		$16,112		$16,112	0.211	$3,399
24		$16,112		$16,112	0.197	$3,176
25		$16,112	$88,037	$104,149	0.184	$19,190
26		$16,112		$16,112	0.172	$2,774
27		$16,112		$16,112	0.161	$2,593
28		$16,112		$16,112	0.150	$2,423
29		$16,112		$16,112	0.141	$2,265
30		$16,112	$88,037	$104,149	0.131	$13,682
Total	$1,135,204	$483,352	$528,224	$2,146,780	**TPV**	**$1,539,926**
					TPV + 20% Contingency	**$1,847,912**
					Total Cost + 0% Tax ($)	**$2,161,600**
					Lower end of TPV Range at -30%	**$1,077,948**
					Upper end of TPV Range at +50%	**$2,309,890**

Table J.5 Alternative 5. Calculations of Total Present Value (Lower and Upper Ranges)

Year	Capital Cost ($)	Annual Cost ($)	Periodic Cost ($) (5-Year Review)	Total Cost + 0% Tax ($)	Discount Factor at 7%	Present Value at 7%
0	$4,153,878			$4,153,878	1.000	$4,153,878
1					0.935	
2					0.873	
3					0.816	
4					0.763	
5					0.713	
6					0.666	
7					0.623	
8					0.582	
9					0.544	
10					0.508	
11					0.475	
12					0.444	
13					0.415	
14					0.388	
15					0.362	
16					0.339	
17					0.317	
18					0.296	
19					0.277	
20					0.258	
21					0.242	
22					0.226	
23					0.211	
24					0.197	
25					0.184	
26					0.172	
27					0.161	
28					0.150	
29					0.141	
30					0.131	
Total	$4,153,878			$4,153,878	**TPV**	**$4,153,878**
					TPV + 20% Contingency	**$4,984,654**
					Total Cost + 0% Tax ($)	**$4,153,878**
					Lower end of TPV Range at -30%	**$2,907,715**
					Upper end of TPV Range at +50%	**$6,230,817**