Final
Remedial Investigation Report, Volume I
Tobyhanna Artillery Range Formerly Used Defense Site
Tobyhanna, Pennsylvania

USACE FUDS Property
No. CO3PA0396

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Remedial Investigation Report

Tobyhanna Artillery Range Formerly Used Defense Site

Tobyhanna, Pennsylvania

USACE FUDS Property No. CO3PA0396

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LIST OF ACRONYMS AND ABBREVIATIONS

A-A	anti-aircraft
AEDA	Ammunition, Explosives, and Dangerous Articles
AET	apparent effect threshold
ALM	Adult Lead Model
AOC	area of concern
AR	Army regulation
AOI	area of interest
ARAR	applicable or relevant and appropriate
ASR	Archives Search Report
AT	anti-tank
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient Water Quality Criteria
bgs	below ground surface
BIP	blow-in-place
BTAG	Biological Technical Assistance Group
BZ	buffer zone
CAA	Clean Air Act
CCC	criteria continuous concentration
CCME	Canadian Council of Ministers of the Environment
CEHNC	U.S. Army Corps of Engineers, Huntsville Engineering and Support Center
CENAB	U.S. Army Corps of Engineers, Baltimore District
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERFA	Community Environmental Response Facilitation Act
CFR	Code of Federal Regulations
cm	centimeter
cmc	criteria maximum concentration
COEC	chemical of ecological concern
COPC	chemical of potential concern

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

CQCP	Contractor Quality Control Plan
CSM	conceptual site model
CWM	chemical warfare material
DAR	Daily Activity Report
DASA	Deputy Assistant Secretary of the Army
dB	decibel
dBA	decibel - A-weighted scale
dBC	decibel - C-weighted scale
DCNR	Pennsylvania Department of Conservation and Natural Resources
DERP	Defense Environmental Restoration Program
°F	degrees Fahrenheit
DGM	digital geophysical mapping
DGPS	differential global positioning system
DID	Data Item Description
DMM	discarded military munitions
DOD	U.S. Department of Defense
DOI	U.S. Department of Interior
DOT	U.S. Department of Transportation
DQCR	Daily Quality Control Report
DQO	data quality objective
DSM	Division Safety Manager
DTL	Design Team Leader
EA	environmental assessment
EE/CA	engineering evaluation and cost analysis
EFH	Exposure Factors Handbook
EHS	extremely hazardous substances
EIS	environmental impact statement
EM	electromagnetic
EO	Executive Order

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

EOD	explosive ordnance disposal
EOR	explosive ordnance reconnaissance
EPA	U. S. Environmental Protection Agency
EPC	exposure point concentration
EPIC	Environmental Photographic Interpretation Center (EPA)
EPP	Environmental Protection Plan
ERA	ecological risk assessment
ER-L	effects range-low
ESOH	Environment, Safety, and Occupational Health
ESRI	Environmental Systems Research Institute
FGDC	Federal Geographic Data Committee
FP	firing point
FS	feasibility study
ft	feet
FUDS	Formerly Used Defense Site
GIS	geographic information system
GM	geometric mean
GPO	geophysical prove-out
GPS	global positioning system
GSD	geometric standard deviation
HE	high explosives
HFA	Human Factors Applications, Inc.
H&S	health and safety
HTW	hazardous or toxic waste
HTRW	hazardous, toxic or radiological wastes
Hz	Hertz
IA	impact area
IAR	instrument-aided reconnaissance
IME/DOT	Institute of Makers of Explosives/U.S. Department of Transportation
INPR	Inventory Project Report

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

LEL	lowest effect level
LOAEL	lowest-observed-adverse-effect level
LOEC	lowest-observed-effect concentration
m	meter
MAG	magnetometric
MC	munitions constituents
MD	munitions debris
M&D	mag and dig
MDL	method detection limit
MEC	munitions and explosives of concern
µg/dl	micrograms per deciliter
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µsec	microsecond
mg/kg	milligrams per kilogram
MGFD	munition with the greatest fragmentation distance
mm	millimeter
MMR	Military Munition Response
MMRP	Military Munitions Response Program
MOU	memorandum of understanding
MPM	most probable munition
mph	miles per hour
MPPEH	materials potentially presenting an explosive hazard
MR	munitions response
MS	Microsoft®
MSC	medium-specific concentration
MSD	minimum separation distance
MSDS	Material Safety Data Sheet
mV	milliVolts
NAAQS	National Ambient Air Quality Standards

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

NAD	North American Datum
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NDAI	No DOD Action Indicated
NE	Northeast
NIH	National Institute of Health
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effect level
NONEL	nonelectrical
NSTP	National Status and Trends Program
nT	nanoteslas
OB/OD	open burning/open detonation
OE	ordnance and explosives (OE is replaced by MEC in this report)
OE MCX	Ordnance and Explosives Mandatory Center of Expertise
OERIA	Ordnance and Explosive Risk Impact Assessment
OESS	Ordnance and Explosives Safety Specialist
OEW	ordnance and explosive waste
OMEE	Ontario Ministry of the Environment and Energy
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
OU	operable unit
PA	preliminary assessment
PADEP	Pennsylvania Department of Environmental Protection
PAH	polycyclic aromatic hydrocarbon
PC	personal computer
PCB	polychlorinated biphenyl
PCE	Project Controls Engineer
PDA	Personal Digital Assistant
PEL	permissible exposure limit
PEL	probable effect level

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

PGC	Pennsylvania Game Commission
PHA	public health assessment
PM	Project Manager
POC	Point-of-Contact
PRG	preliminary remediation goal
QA	Quality Assurance
QC	Quality Control
RA	Reconnaissance area
RAC	Risk Assessment Code (USACE)
RBC	risk-based concentration
RBSC	risk-based screening concentration
RDX	Royal demolition explosive
RF	range safety fan
RI	remedial investigation
ROD	Record of Decision
RQ	reportable quantity
RTK	real-time kinematic
SAP	Sampling and Analysis Plan
SERDB	socially, economically, restricted businesses
SI	site inspection
SLC	screening level concentration
SLERA	screening level ecological risk assessment
SLRA	screening level risk assessment
SNR	signal-to-noise ratio
SOW	scope of work
SQL	sample quantitation limit
SSHP	Site Safety and Health Plan
SSTT	Spiked-Sediment Toxicity Test
SUXOS	Senior UXO Supervisor
SVOC	semivolatile organic compound

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

SW	Southwest
SW/SD	surface water/sediment
TA	target area
TCL	Target Compound List
TCRA	Time Critical Removal Action
THQ	target hazard quotient
TL	Team Leader
TNT	trinitrotoluene (an explosive)
TOC	total organic carbon
TOAR	Tobyhanna Artillery Ranges
TPP	Technical Project Planning
TYAD	Tobyhanna Army Depot
UCL	upper confidence limit
U.S.C.	United States Code
UPS	uninterruptible power supply
USACE	U.S. Army Corps of Engineers
U.S.ft	U.S. Survey Feet
USFWS	U. S. Fish and Wildlife Service
USRADS	Ultrasonic Ranging Data System
UTM	Universal Transverse Mercator
UXO	unexploded ordnance
UXOQCS	UXO Quality Control Specialist
UXOSO	UXO Safety Officer
VOC	volatile organic compound
WAAS	Wide Area Augmentation System
WAR	Weekly Activity Report
WESTON	Weston Solutions, Inc.
WQC	water quality criteria
WWII	World War II

EXECUTIVE SUMMARY

The Pennsylvania Department of Environmental Protection (PADEP) is conducting a remedial investigation/feasibility study (RI/FS) at the Tobyhanna Artillery Range Formerly Used Defense Site (TOAR-FUDS) located in Tobyhanna, Pennsylvania (PA). The RI and FS reports for the TOAR-FUDS are being prepared and submitted as separate documents. This report represents the RI report, with the FS report to be submitted as a standalone document.

The majority of the TOAR-FUDS is located in Monroe County, with a small portion of the northeast quadrant of the site falling within Wayne County, in northeastern Pennsylvania. The TOAR-FUDS was composed of approximately 21,100 acres. The Army originally leased the lands of the TOAR-FUDS in 1912 for the purpose of troop training. Later that year the Army formally acquired the lands. Both regular Army and National Guard field artillery units from throughout the Northeast and Mid-Atlantic states trained at Tobyhanna. During World War I, the reservation also served as a training center for tank and ambulance units. Prior to World War II, training was expanded to include cadets from the Army's Military Academy at West Point. Training reached its height during World War II with intensive artillery training being conducted. After the end of World War II, both the mission and activities of the artillery ranges were phased out.

In 1949, 14,000 acres were deeded to the Commonwealth of Pennsylvania's Game Commission. This land formed the basis for State Game Lands Number 127 (Game). Also in 1949, an additional 7,080 acres were deeded to the Commonwealth of Pennsylvania's Department of Forest and Waters. This land formed the basis for the Tobyhanna State Park (Park).

On 1 October 1952, the Commonwealth of Pennsylvania sold 1,418.49 acres of the area back to the U.S. Government. This tract of the original TOAR was required for the establishment and development of the Tobyhanna Signal Depot, which was officially commissioned on 1 February 1953 and remains active today, having been renamed the Tobyhanna Army Depot (TYAD).

Today, the Park covers the northeastern third of the site, and is managed by the Pennsylvania Department of Conservation and Natural Resources (DCNR). The Park currently contains minimal infrastructure, and is used for multiple recreational purposes, including camping, boating, swimming, hunting, fishing, hiking, snowmobiling, and mountain biking. Significant upgrades to infrastructure in the Park are planned for 2006. Game covers the remaining southwestern portion of the site and is managed by the Pennsylvania Game Commission (PGC). Game serves as a habitat for large and small game animals that are hunted in season, and features several lakes and streams that are fished regularly. The PGC uses some of the land in Game for food plots and timber sales.

Munitions and explosives of concern (MEC) exist on the TOAR-FUDS property. The term MEC distinguishes specific categories of military munitions that may pose unique explosive safety risks, including the following:

- Unexploded ordnance (UXO) – Military munitions that fulfill the following criteria:
  - Have been primed, fuzed, armed, or otherwise prepared for action;
  - Have been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material; and
  - Remain unexploded either by malfunction, design, or any other cause (United States Code [U.S.C.] §2710 (e) (9)).
- Discarded military munitions (DMM) – Military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal. The term does not include UXO, military munitions that are being held for future use or planned disposal, or military munitions that have been properly disposed of consistent with applicable environmental laws and regulations. (10 U.S.C. §2710 (e) (2)).
- Munitions constituents such as TNT and RDX present in high enough concentrations to pose an explosive hazard (U.S. Army, 2005).

The nature and extent of MEC was investigated by sampling for UXO, DMM and Munitions Constituents (MC), which are any materials originating from UXO, discarded military munitions, or other military munitions, including explosive and non explosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions (10 U.S.C. §2710 (e)(4)).

No DMM have been recovered at the TOAR-FUDS, and no munitions constituents such as TNT and RDX have been found in high enough concentrations to pose an explosive hazard. All MEC recovered at the site to date have been classified as UXO. UXO that have been recovered during previous activities at the TOAR-FUDS include the following:

- 278 UXO recovered in Park during the 1998 Human Factors Applications, Inc. (HFA) time critical removal action (TCRA).
- 228 UXO recovered on-post at TYAD during the 1998 HFA construction support activities.
- 7 UXO recovered on-post at TYAD during the 2004 WESTON construction support activities.
- 1 UXO recovered in Game during the 2004 WESTON TCRA.
- 3 UXO recovered in Park during the 2004 WESTON site visit.
- 2 UXO recovered in Park during the 2004 CENAB site visit.

The objective of the RI/FS is to identify the most appropriate remedial alternative(s) to address the UXO risk at the TOAR-FUDS. The RI is intended to adequately characterize the nature and extent of UXO contamination at the site based on current and future intended land use for the purpose of developing and evaluating effective remedial alternatives. As part of the RI, risks to human health, safety, and the environment were evaluated based on current and future use of the property. The following data quality objectives (DQOs) were established for the RI at the TOAR-FUDS to ensure that the overall objectives of the RI were met:

- Characterize the nature, location, and concentration of UXO at the TOAR-FUDS based on the current and future intended land use of recreational activities (hunting, camping, hiking, fishing, etc.).
- Perform geophysical prove-out (GPO) to determine appropriate methods, instrumentation, and positioning devices needed to successfully locate UXO at the TOAR-FUDS. Perform GPO in accordance with data item description (DID) MR-005-05A, Geophysical Prove-Out (GPO) Plan and Report.
- Perform geophysical and intrusive sampling activities at the TOAR-FUDS using procedures deemed appropriate in the GPO for data processing, data correction, data analysis, anomaly selection and reacquisition, and quality control. Meet DQOs defined by CEHNC.
- Intrusively investigate enough acreage in each area of interest (AOI) at the TOAR-FUDS using digital methods to satisfy minimum required acreage calculated by UXO Estimator for target density of 0.5 UXO/acre at a 95% confidence level.
- Perform sample acquisition, chemical analysis and chemical parameter measurements so that the resulting data meet and support data use requirements. Acquire, document, verify and report chemical data to ensure that the specified precision, accuracy,

representativeness, comparability, completeness and sensitivity requirements are achieved.

A combination of visual searching, and digital and analog UXO detection technologies in conjunction with acoustic positioning systems and hand-held global positioning systems (GPS), respectively, was used during the RI at the TOAR-FUDS to characterize the nature and extent of UXO at the site.

In addition to UXO hazards, potential contamination from MC at the site was evaluated relative to impacts to both human health and the environment (i.e., ecological impacts). Because sampling for MC had not been previously conducted at the TOAR site, sampling was conducted at a site inspection (SI) level based on biased high sampling locations (i.e., ordnance features, such as detonation craters and within impact areas), and analyzed for metals and explosives to determine if contaminant levels warranted further investigation.

The results of the investigation for UXO were used to evaluate risk associated with UXO at the TOAR-FUDS. A qualitative risk evaluation was conducted using the *Ordnance and Explosives Risk Impact Assessment* (OERIA), Interim Guidance document (USACE, 2001) to assess explosive safety risks to the public at the TOAR site. The potential risks posed by UXO were characterized qualitatively by evaluating the following three primary risk factors:

1. Presence of a UXO source.
2. Site Characteristics – Affect the accessibility or pathway between the source and human receptor.
3. Human Factors – Defines the number of receptors and type of activities that may result in direct contact between a receptor and a UXO source.

The results of environmental sampling for MC were compared to background concentrations and applicable benchmarks to provide an initial characterization of the potential risks to human health and ecological receptors at the TOAR-FUDS and to determine if additional evaluation or sampling is needed. The samples were analyzed three ways: (1) results for Park only, (2) results for Game only, and (3) results for Park and Game combined. The results were analyzed three ways to ensure that elevated concentrations in either Park or Game would not be lost in a combined, site wide assessment.

The results of the site investigation and risk evaluation for UXO identified several areas at the TOAR-FUDS with high risk due to the presence of UXO items. The results of the sampling and risk assessment for MC indicated that additional evaluation or sampling for MC is not warranted. Nine areas of concern (AOCs) were identified at the TOAR-FUDS and are summarized in Table ES-1. Remedial alternatives for the AOCs identified will be evaluated as part of the FS.

Table ES-1
Areas of Concern at the TOAR-FUDS

Area of Concern	Location	Total AOC Acreage	Wet AOC Acreage[1]	Total Accessible Acreage[2]	Acres Investigated During 2004 RI		Approx. Acres Investigated During All Previous Investigations	Total Approx. Acres Investigated in AOC[3]	UXO Recovered in AOC During 2004 RI	UXO Recovered in AOC During All Previous Investigations	Total UXO Recovered in AOC[4]	Physical Features and Land Uses	UXO Risk
					DGM	IAR							
AOC TOAR-1	Lake Watawga Area	265	99	166	0.42	54.05	1	55	2	2	4	Adjacent residential housing	High
AOC TOAR-2	Impact Area Park	1103	266	837	8.59	25.64	201	235	37	270	307	Camping, hiking, fishing, mountain biking, snowmobiling	High
AOC TOAR-3	Impact Area Park	254	98	156	4.44	2.23	2	9	1	6	7	Camping, hiking, fishing, mountain biking, snowmobiling	High
AOC TOAR-4	Impact Area Game	656	142	514	6.42	9.21	0	16	28	0	28	Hunting, fishing, hiking, mountain biking, snowmobiling	High
AOC TOAR-5	Impact Area Game	625	126	499	10.45	6.64	0	17	7	0	7	Hunting, fishing, hiking, mountain biking, snowmobiling	High
AOC TOAR-6	Buffer Zone Park	2908	612	2296	8.91	54.29	3	66	0	5	5	Camping, fishing, hiking, mountain biking, snowmobiling	Low-Moderate
AOC TOAR-7	Buffer Zone Game	7304	1577	5727	11.21	36.25	20	67	3	1	4	Hunting, fishing, hiking, fishing, mountain biking, snowmobiling	Low-Moderate
AOC TOAR-8	Other Areas Park	3790	525	3265	9.20	49.37	0	59	0	0	0	Adjacent residential housing, hiking, fishing, mountain biking, snowmobiling	Low
AOC TOAR-9	Other Areas Game	4195	1847	2348	13.66	34.40	7	55	0	0	0	Adjacent residential housing, hunting, fishing, hiking, mountain biking, snowmobiling	Low

[1]Wet acreage based on GIS coverage of TOAR-FUDS from 2000, and includes lakes, ponds, streams, wetlands, etc.

[2]Total accessible acreage = Total acreage – Total wet acreage.

[3]Total approximate acres investigated = Acres investigated during 2004 RI + Approximate acres investigated during all previous investigations.

[4]Total UXO recovered = UXO recovered during 2004 RI + UXO recovered during all previous investigations.

1. INTRODUCTION

The Pennsylvania Department of Environmental Protection (PADEP) is conducting a remedial investigation/feasibility study (RI/FS) at the Tobyhanna Artillery Range Formerly Used Defense Site (TOAR-FUDS) located in Tobyhanna, Pennsylvania (PA). Munitions and explosives of concern (MEC) exists on property formerly owned or leased by the Department of Army. This site falls under the Defense Environmental Restoration Program - Formerly Used Defense Sites (DERP-FUDS). However, due to funding constraints, the U.S. Army Corps of Engineers (USACE) was unable to execute the project at this time. To aid the process and speed the protection of the public and site workers, PADEP has agreed to both contract and fund the RI/FS phase of the Munitions Response (MR). The USACE Baltimore District (CENAB) has agreed to support PADEP with UXO technical expertise in the execution of the project. To facilitate this support, PADEP and CENAB have entered into a Memorandum of Understanding (MOU) that describes each agency's, roles, responsibilities, and authorities. PADEP, with concurrence from CENAB, selected Weston Solutions, Inc. (WESTON) of West Chester, PA to serve as the contractor for this project.

The project was originally scoped with the objective to conduct adequate field investigations to allow the preparation and approval of an Engineering Evaluation and Cost Analysis (EE/CA) for the project site. This work focused primarily on the safety hazards associated with UXO contamination as part of a removal response action. In May 2004, the Department of the Army published ER 200-3-1, Formerly Used Defense Sites (FUDS) Program Policy. This policy requires that all response activities undertaken by USACE that address Military Munitions Response Program (MMRP) sites as part of the FUDS program be conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), Executive Order (EO) 12580, Superfund Implementation (January 23, 1986); EO 13016, Superfund Amendments (August 28, 1996); and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] Part 300).

The ultimate objective under CERCLA is to protect human health, welfare, and the environment from hazards associated with MEC from MMRP sites (see Subsection 1.4 for definitions of MMRP terms). Consequently, the scope of the project was transitioned from an EE/CA to an

RI/FS to meet the substantive requirements of ER 200-3-1. Potential chemical contamination from MEC at the site was also evaluated relative to impacts to both human health and the environment (i.e., ecological impacts). Because environmental sampling had not been previously conducted at the TOAR-FUDS, environmental sampling was conducted at a site inspection (SI) level based on biased high sampling locations to determine if contaminant levels warranted further investigation.

A formal, systematic technical planning process (TPP) involving four phases of planning activities, as defined in USACE EM 200-1-2, was not followed for this project due to its aggressive schedule and evolving scope. However, all appropriate regulating agencies and stakeholders, including PADEP, CENAB, WESTON, the Pennsylvania Game Commission (PGC), and the Pennsylvania Department of Conservation and Natural Resources (DCNR) were involved in all phases of planning, including identification of project scope, review of existing data, identification of additional data needs, development of the work plan, and scheduling.

1.1 PROJECT AUTHORIZATION

WESTON was authorized to perform the EE/CA under PADEP Contract ME359183, Project Number ISRC-2-078. This scope has been transitioned to an RI/FS (with concurrence from PADEP, CENAB, and WESTON) to meet the requirements of ER 200-3-1.

1.2 PURPOSE AND SCOPE

The objective of the RI/FS is to identify the most appropriate remedial alternative(s) to address the MEC risk at the TOAR-FUDS. The RI is intended to adequately characterize the nature and extent of MEC contamination at the site based on current and future intended land use for the purpose of developing and evaluating effective remedial alternatives. As part of the RI, risks to human health, safety, and the environment were evaluated based on current and future use of the property. The following data quality objectives (DQOs) were established for the RI at the TOAR-FUDS to ensure that the overall objectives of the RI were met:

- Characterize the nature, location, and concentration of MEC at the TOAR-FUDS based on the current and future intended land use of recreational activities (hunting, camping, hiking, fishing, etc.).

- Perform geophysical prove-out (GPO) to determine appropriate methods, instrumentation, and positioning devices needed to successfully locate MEC at the TOAR-FUDS. Perform GPO in accordance with data item description (DID) MR-005-05A, Geophysical Prove-Out (GPO) Plan and Report. (Details are provided in Appendix K of the EE/CA Work Plan.)

- Perform geophysical and intrusive sampling activities at the TOAR-FUDS using procedures deemed appropriate in the GPO for data processing, data correction, data analysis, anomaly selection and reacquisition, and quality control. Meet DQOs defined by CEHNC. (Details are provided in Section 3 of the EE/CA Work Plan and discussed in Section 3 of this report.)

- Intrusively investigate enough acreage in each area of interest (AOI) at the TOAR-FUDS using digital methods to satisfy minimum required acreage calculated by UXO Estimator for target density of 0.5 unexploded ordnance (UXO)/acre at a 95% confidence level. (Details are provided in subsection 3.1.1 of this report.)

- Perform sample acquisition, chemical analysis and chemical parameter measurements so that the resulting data meet and support data use requirements. Acquire, document, verify and report chemical data to ensure that the specified precision, accuracy, representativeness, comparability, completeness and sensitivity requirements are achieved for the criteria listed in subsection 7.2.

The primary objective of the FS is to develop and analyze several potential alternatives to mitigate, reduce, or eliminate unacceptable risk from site-related contaminants. These alternatives will be screened for effectiveness, cost, and implementability. Alternatives that are not screened out will then be subject to a more rigorous analysis based on the nine NCP criteria. The purpose of this evaluation is to provide decision-makers with enough information to select the most appropriate remedial alternative(s) for the TOAR site.

The RI and FS reports for the TOAR-FUDS are being prepared and submitted as separate documents. This report represents the RI report, with the FS report to be submitted as a stand-alone document. All comments and responses submitted and addressed for this report are provided in Appendix A. A record of community involvement in this project is provided in Appendix B.

1.3 REPORT ORGANIZATION

This RI report is structured as follows:

- **Executive Summary**
  - Brief history of site
  - Remedial Investigation objectives
  - Field work
  - Risk evaluation for UXO and Munitions Constituents (MC)
  - Results
- **Section 1 – Introduction**
  - Project Authorization
  - Purpose and Scope
  - Report Organization
  - Terminology
- **Section 2 – Site Description**
  - Site Location
  - Physical Description
  - Environmental Setting
  - Current and Projected Land Use
  - Demographic Profile
  - History
  - Previous Investigations
- **Section 3 – Site Investigation**
  - Site Investigation for UXO (including instrumentation, anomaly identification, and intrusive investigation)
  - Site Investigation for MC (including environmental sampling)
- **Section 4 – Site Characterization**
  - Source, Nature, and Extent of UXO (analysis of historical records and site investigation)
  - Source, Nature, and Extent of MC (including surface soil, sediment, surface water and fill area)
  - Revised CSM
- **Section 5 – Preliminary Applicable or Relevant and Appropriate Requirements and To Be Considered Criteria**

- **Section 6 – Contaminant Fate and Transport**
- **Section 7 – Risk Evaluation**
  - Risk Evaluation for UXO (including definition of factors)
  - Screening Level Risk Assessment for MC (including human-health and ecological screening level risk assessment)
- **Section 8 – Institutional Analysis**
  - Methodology
  - Recommendations
- **Section 9 – Summary and Conclusions**
  - RI Results
  - Discussion of Uncertainty
  - Conclusions
- **Section 10 – References**
- **Appendices**
  - Appendix A - Comments and Responses
  - Appendix B - Community Involvement
  - Appendix C - Timber Sales Areas in Game
  - Appendix D - Geophysical Prove-Out Report and Memorandum
  - Appendix E - Quality Control Log
  - Appendix F - DGM Survey Grid Corner and Monument Data and Survey Field Notes
  - Appendix G -USACE Quality Assurance Plan
  - Appendix H - Photo Log
  - Appendix I - DGM Grid Maps
  - Appendix J - Dig Sheets
  - Appendix K - Root-Cause Analysis Memorandums
  - Appendix L - Demolition Activity Logs
  - Appendix M - Documentation of Disposition of Munitions Potentially Presenting an Explosive Hazard, Munitions Debris, and Wastes
  - Appendix N - Analytical Results
  - Appendix O - Supplemental Risk Assessment Tables
  - Appendix P - Institutional Analysis Report

1.4 TERMINOLOGY

On 21 April 2005, the Deputy Assistant Secretary of the Army for Installations and Environment issued a memorandum providing standard definitions to be used in Munitions Responses (MR).

The purpose was to ensure clarity and consistency in the use of terms for a MR. While most of the terminology in the memorandum is well established, several terms are a departure from the traditional terminology and are defined in the following paragraphs. The conceptual site model (CSM) will adhere to the terminology as set forth in the memorandum (U.S. Army, 2005).

Discarded Military Munitions (DMM) – Military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal. The term does not include UXO, military munitions that are being held for future use or planned disposal, or military munitions that have been properly disposed of consistent, with applicable environmental laws and regulations. (10 United States Code [U.S.C.] §2710 (e)(2)).

Material Potentially Presenting an Explosive Hazard (MPPEH) – Material potentially containing explosives or munitions (e.g., munitions containers and packaging material; munitions debris remaining after munitions use, demilitarization, or disposal; and range-related debris); or material potentially contaminated with a high enough concentration of explosives such that the material presents an explosive hazard (e.g., equipment, drainage systems, holding tanks, piping, ventilation ducts associated with munitions production, demilitarization, or disposal operations). Excluded from MPPEH are munitions within a U.S. Department of Defense (DOD)-established munitions management system and other hazardous items that may present explosion hazards (e.g., gasoline cans, compressed gas cylinders) that are not munitions and are not intended for use as munitions (U.S. Army, 2005).

Munitions Response (MR) – Response actions, including investigation, removal, and remedial actions to address the explosives safety, human health, or environmental risks presented by UXO, DMM, or munitions constituents (MC) (U.S. Army, 2005).

Munitions and Explosives of Concern (MEC) – This term distinguishes specific categories of military munitions that may pose unique explosive safety risks, such as:

- UXO, as defined in 10 U.S.C. 2710 (e)(9).
- DMM, as defined in 10 U.S. C. 2710 (e)(2).

- Munitions constituents (e.g., trinitrotoluene [TNT], Royal Demolition Explosive [RDX]) present in high enough concentrations to pose an explosive hazard (U.S. Army, 2005).

Munitions Constituents (MC) – Any materials originating from UXO, discarded military munitions, or other military munitions, including explosive and non explosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions (10 U.S.C. 2710 (e)(4)). At the TOAR-FUDS, potential MC consists of metals and explosives residuals.

Munitions Debris – Remnants of munitions (e.g., penetrators, projectiles, shell casings, links, fins) remaining after munitions use, demilitarization or disposal (U.S. Army, 2005).

Range-Related Debris – Debris other than munitions debris collected from operational ranges or from former ranges (e.g., targets). Note: Range Related Debris is considered MPPEH until technically qualified personnel have done the following:

1. Inspected, verified, and certified that it does not present an explosive hazard, and consequently is safe for any person (e.g., the general public) to receive; or
2. Inspected, verified, and certified it as to the explosive hazard it may present to a qualified receiver (U.S. Army, 2005).

Unexploded Ordnance (UXO) – Military munitions that fulfill the following criteria:

1. Have been primed, fuzed, armed, or otherwise prepared for action;
2. Have been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material; and
3. Remain unexploded either by malfunction, design, or any other cause (U.S.C. §2710 (e)(9)).

2. SITE DESCRIPTION

2.1 SITE LOCATION

The project site is located in Monroe County, with a small section of the northern portion of the TOAR-FUDS within Wayne County, in northeastern Pennsylvania, as shown in Figure 2-1. The TOAR-FUDS is located approximately 90 miles north of Philadelphia, 75 miles west of New York, and 116 miles east of Harrisburg. Figure 2-2 shows the approximate boundaries of the TOAR-FUDS. The TOAR-FUDS consists of two adjacent land areas owned by the Commonwealth of Pennsylvania and divided by Interstate 380 (I-380). The northeastern portion is managed by the DCNR and is comprised of portions of Tobyhanna State Park (Park). The southwestern portion is managed by the PGC and is comprised of portions of the Pennsylvania State Game Lands Number 127 (Game). Physical features and land uses at the TOAR-FUDS are shown in Figure 2-3 and described in the following subsections.

2.2 PHYSICAL DESCRIPTION

2.2.1 Climate

During the summer months, the weather is generally warm and sunny with low humidity. Temperature ranges from 70º to 80º Fahrenheit (ºF) in the afternoons with nighttime lows ranging from 50º to 60ºF. In the summer, 90º days can be reached, but only occasionally. Thunderstorms and afternoon showers reach a peak in June, July, and August. They occur on an average of 8 days per month and are usually of short duration. Of the annual sunshine, 60% occurs during the summer. The prevailing wind is from the southwest with an average wind speed of 7 miles per hour (mph). The average relative humidity is 50%. The last freeze in spring occurs on or around May 15th with the first freeze occurring in fall on approximately September 28th. Autumn is relatively dry with an occasional storm. Winter weather normally begins by mid-November and extends through March. The season is rather cloudy and high temperatures remain around the freezing mark. Low temperatures are in the mid-teens in January and February, but increase about 5º to 7º each month until the last freeze on or around May 15th.

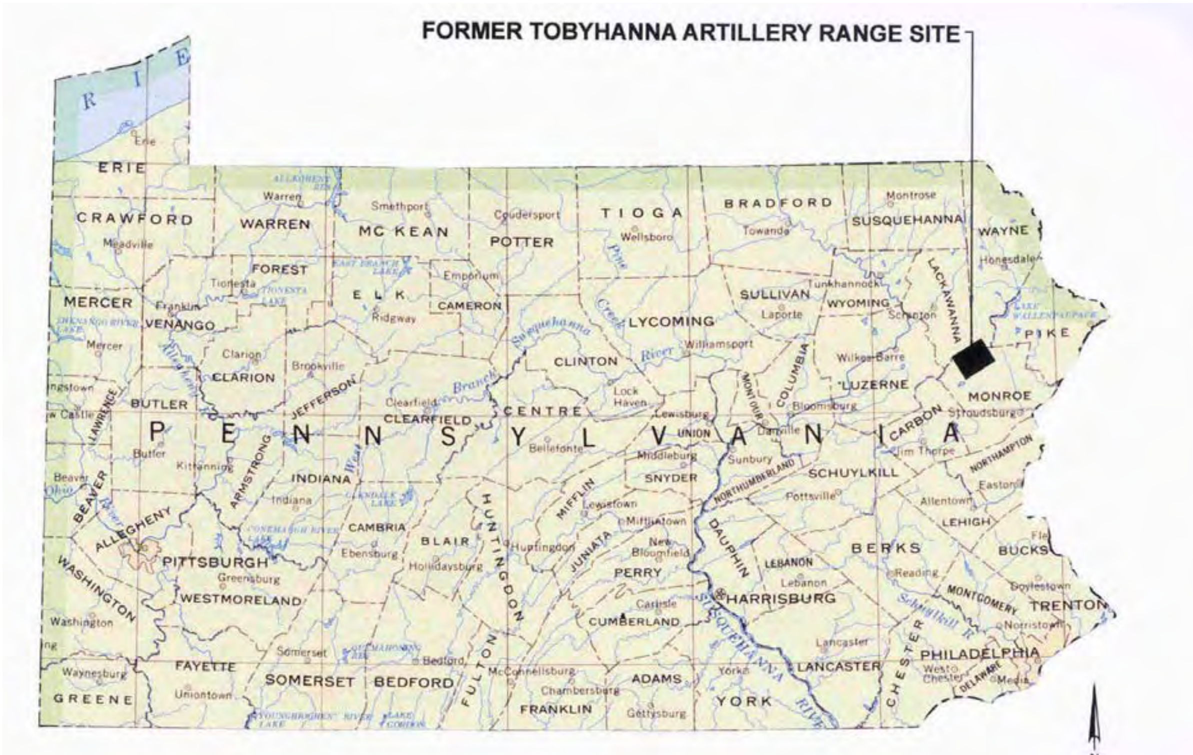

Figure 2-1 TOAR-FUDS Site Location Map

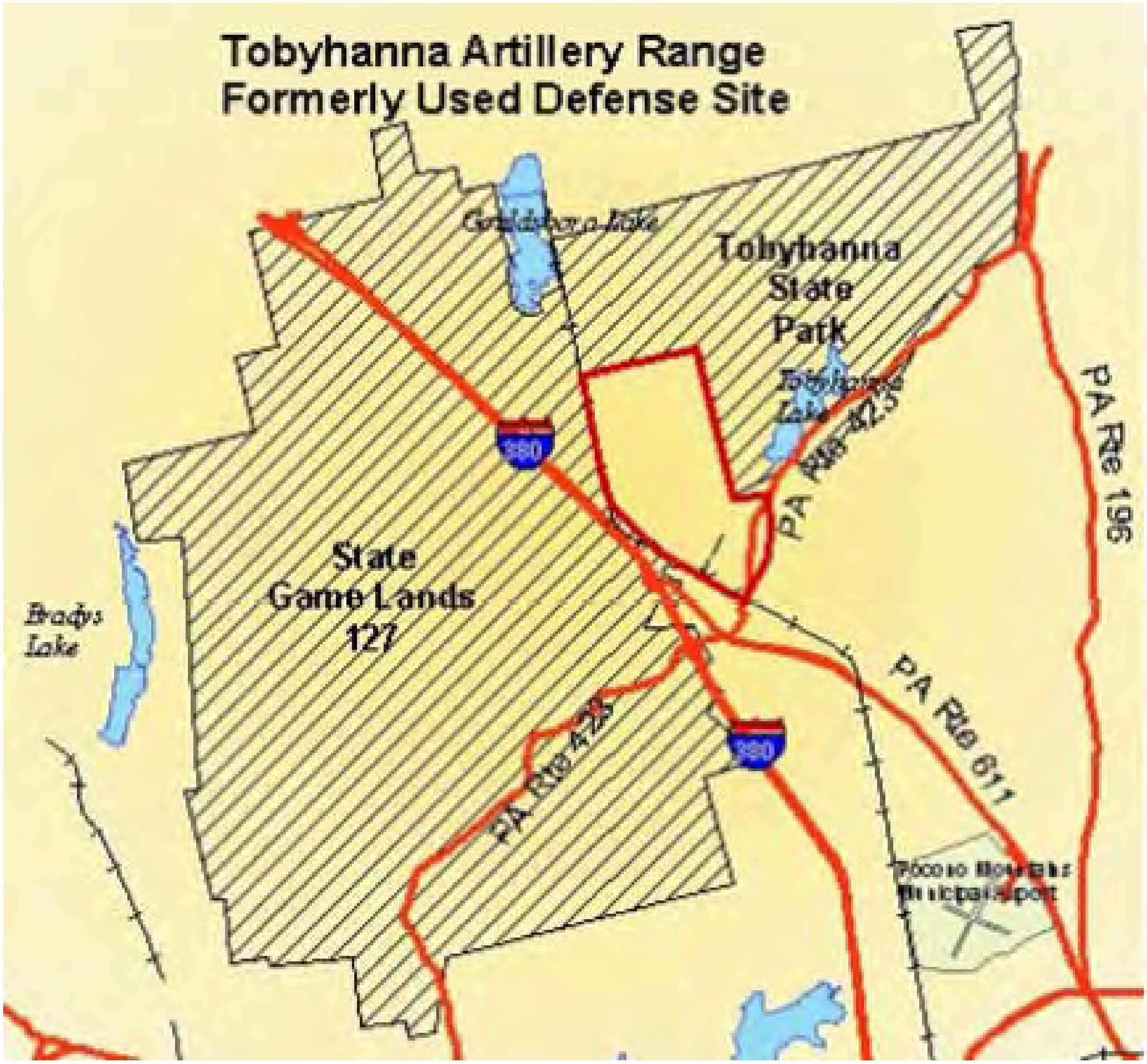

Figure 2-2 TOAR-FUDS Approximate DERP-FUDS Project Boundary[1]

[1] Figure courtesy of the U.S. Army Corps of Engineers, Baltimore District.

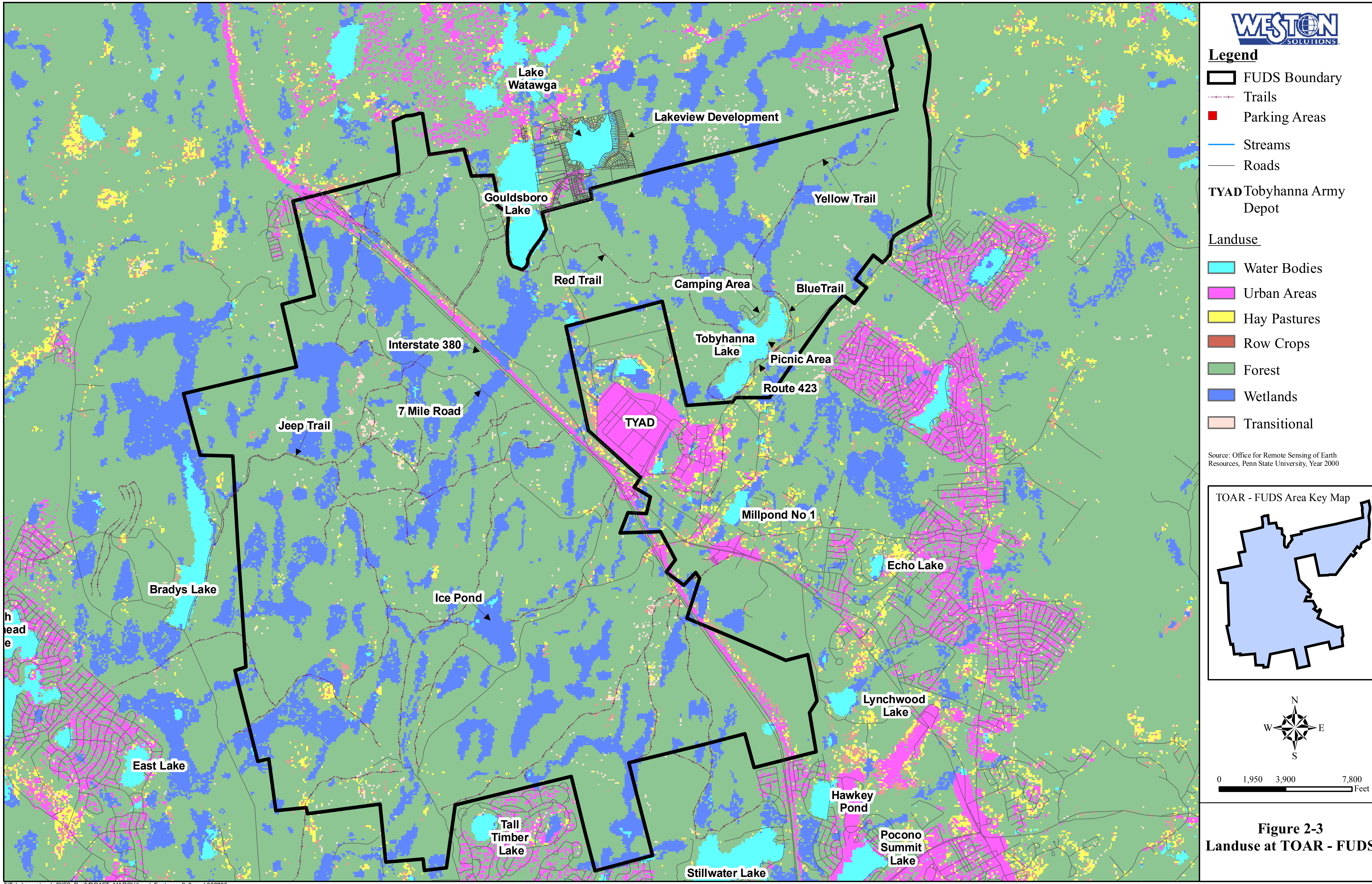

Figure 2-3
Landuse at TOAR - FUDS

The lowest temperature recorded at Mount Pocono, located approximately 5 miles southeast of the site, was -35º F on 14 January 1912. Snowfall averages from 2 to 10 inches per storm, with a normal snow season receiving 50 to 60 inches of snow. During the winter, snow covers the ground approximately 65% of the time.

2.2.2 Physiography

The area may be characterized as partly swampy and heavily wooded, with dense brush and outcroppings of bedrock. The terrain has slopes ranging from 0 to 20%. Based on the aerial photographs compiled by the U.S. Environmental Protection Agency's (EPA's) Environmental Photographic Interpretation Center (EPIC), which are discussed in subsection 2.7.1, when the artillery range was in operation, very few trees existed on-site. Now, about 81% of the site is woodlands. Soil erosion, low water capacity in the rapidly permeable soils, and insufficient drainage in the low-lying areas cause major problems for development of the area.

The majority of the site is in an undeveloped state. Several major roads and railways traverse the site, including Interstate 380, which runs northwest-southeast through Game, and Pennsylvania Route 423, which runs northeast-southwest through parts of Park and Game. Infrastructure items built by the U.S. Army (Army) (roads and trails) have, in most instances, grown over. There are few manmade features remaining on the site. The Park covers the northeastern third of the site, and contains minimal infrastructure. The site is currently used for recreational purposes, including hunting, fishing, hiking, snowmobiling, and mountain biking. Game covers the remaining southwestern portion of the site. It is a principal hunting area for Pennsylvania residents and has several lakes and streams that are fished regularly. The Pennsylvania Game Commission uses some of the land in Game for food plots and timber sales. Also, there is a growing population of suburban dwellers who have purchased property in the surrounding area to have weekend and "getaway" residences due to the abundant opportunities for outdoor recreation. All roads, trails, food plots, and residential housing developments described above are shown in Figure 2-3. Timber sales areas are delineated by the PGC, as shown on the maps provided in Appendix C.

2.2.3 Geologic and Soil Conditions

The TOAR-FUDS areas are located within the Pocono Plateau Section of the Appalachian Plateau Geologic Province. Glaciation throughout this region during Pleistocene geologic time has resulted in a veneer of glacial fill blanketing the land surface. The glacial fills range from stratified drift deposits to unsorted glacial till. The glacial till consists of mixtures of clay, silt, sand, gravel, and boulders. The glacial fills are thickest in former stream valleys and thinnest near ridge tops.

Bedrock beneath the glacial deposits consists of the Duncannon and Poplar Gap Members of Catskill Formation of Devonian Geologic Age. Both of these members are composed of interbedded conglomerate, sandstone, siltstone, and shale, ranging from red to medium gray in color. The rocks within the Pocono Plateau are gently folded with the axis of the folds striking to the northeast. Overall, the Catskill formation dips gently to the west, resulting in progressively older members of the formation cropping out to the east.

As a result of glaciation, most of the soils are too stony for cultivation. About 81% of the county is woodlands. Soil erosion, low available water capacity in rapidly permeable soils, and insufficient drainage in wet soil are the major problems in areas developed for recreation.

2.2.4 Hydrology

Groundwater throughout the region generally occurs under unconfined conditions with the groundwater surface being a subdued reflection of the surface topography. Local or semi-confined conditions may occur beneath portions of glacial till deposits that are very low in hydraulic conductivity and within some fractures in the bedrock. Recharge to the water table occurs on topographically high areas, with discharge to streams and marshes in low-lying areas. Rainfall in the region averages 45 inches each year. About 16 to 19 inches of the total annual rainfall infiltrates to the water table. Evaporation losses are less in this region than elsewhere in Pennsylvania due to the high altitude, prolonged snow cover, and low average annual air temperature.

Groundwater is used for potable purposes throughout Monroe County. Most wells in the county derive their water from wells drilled into the bedrock. However, wells drilled in glacial deposits can provide locally high yields where located within stratified drift deposits. Yields of wells within the Duncannon and Poplar Gap Members of the Catskill Formation are moderate to high. Well yield in the bedrock is generally a function of secondary porosity, through the well-developed fracture systems in these rocks. There is essentially no primary porosity within the underlying bedrock. Water quality is generally good, but the water locally is moderately hard, with excessive iron and manganese in some areas.

2.3 ENVIRONMENTAL SETTING

The Pennsylvania Natural Diversity Inventory (PNDI) information system was used to gather information regarding the presence of resources of special concern within the TOAR-FUDS. The information obtained through the PNDI review was used to supplement this section.

2.3.1 Ecosystems

The land at the TOAR-FUDS consists mainly of upland and lowland forests, forested wetland, emergent wetland, and aquatic habitats. Upland environments include heavily forested areas and scattered brush land and other deciduous habitats. Northern hardwood forest is the predominant upland habitat that exists on-site. American beech, red maple, yellow and black birch, and black cherry are very common hardwoods. Striped maple dominates the shrub understory layer. Other tree and shrub species that make up the TOAR-FUDS's upland forested areas include gray birch, hickory, witch hazel, and rhododendron.

Forests in the lower elevations at the TOAR-FUDS are composed of mast producing trees such as American beech. Smaller trees such as hemlock, maples, oaks, and birches dominate the sloped areas of the lower elevations. Other than ferns and club mosses, very little herbaceous ground cover is present within the forest habitat cover type. Damper areas support coniferous species such as eastern hemlock, white pine, red spruce, highbush blueberry, and winterberry. Various types of mosses and lichens can be found growing on many surficial rocks and boulders located throughout this habitat.

Woody species that occur in forested wetlands include red maple, yellow birch, eastern hemlock, red spruce, quaking aspen, rosebay rhododendron, broadleaf meadowsweet, smooth winterberry holly, speckled alder, highbush blueberry, narrowleaf meadowsweet, and winterberry. Herbaceous species that are part of the ground cover include cinnamon fern, sensitive fern, jewelweed, tearthumb, bugleweed, sphagnum moss, various sedges, golden saxifrage, gold thread and mannagrass.

The emergent wetland areas of the TOAR-FUDS include both true emergent and scrub/shrub wetlands. Most of these emergent wetland areas are mixed graminoid-robust emergent marsh lands. The primary vegetation includes broad-leaved cattails, sedges, rushes, and grasses. Floating plants include *Nuphar, Lemna*, and *Wolffia*; submerged plants include *Utricularia*. Shrub species include speckled alder, highbush blueberry, steeplebush, leatherleaf, and sheep-laurel. Other woody vegetation (tree saplings) includes red maple, gray birch, black willow, eastern hemlock, red spruce, and larch.

2.3.2 Wildlife

2.3.2.1 Forested Habitats

Numerous mammal species inhabit the TOAR-FUDS's upland forested habitats including: white-tailed deer, black bear, red squirrel, eastern chipmunk, and deer mouse. Other species that are expected to inhabit this cover type are: opossum, raccoon, bobcat, coyote, gray fox, striped skunk, flying squirrel, porcupine, and gray squirrel.

Bird species that inhabit the upland forests of the TOAR-FUDS include: wild turkey, ruffed grouse, various species of hawks, screech owl, great horned owl, barred owl, woodpeckers, tufted titmouse, eastern phoebe, eastern wood pewee, kinglets, veery, ovenbird, hermit thrush, wood thrush, American robin, cedar waxwing, various vireos, various warblers, scarlet tanager, northern cardinal, rose-breasted grosbeak, rufous-sided towhee, slate-colored junco, northern oriole, black-capped chickadee, nuthatches, blue jay, and American crow.

Reptiles that may be present in this habitat include various snakes such as the black rat snake, copperhead, and timber rattlesnake.

2.3.2.2 Forested Wetlands

Wildlife within the forested wetland habitat cover type at the TOAR-FUDS is abundant. Common mammals include white-tailed deer, gray squirrel, red squirrel, and eastern cottontail. Black bear, porcupines, and raccoons are also expected to occur in this habitat cover type. There are signs of woodpeckers throughout TOAR. Numerous songbirds can be found in this cover type including: wood thrush, nuthatches, sparrows, and wrens. Reptiles found in this cover type include northern water snakes, green frogs, and pickerel frogs.

2.3.2.3 Scrub/Shrub – Emergent Wetlands

Wildlife is most abundant in the scrub/shrub-emergent wetland habitat cover type. Mammals present in this habitat type include white-tailed deer, black bear, beaver, coyote, fox, raccoon, opossum, muskrat, mink, and river otter. Snowshoe hares are also likely to inhabit the shrub/scrub wetland habitats. Bats may also frequent the wetland areas during the evening.

Various song birds use these wetland areas for food and nesting. Species of birds and waterfowl that can be found in or near the edges of this cover type include: great blue heron, green heron, belted kingfisher, wood duck, swamp sparrow, warblers, wrens, red-winged blackbird, black-capped chickadee, American crow, cedar waxwing, American woodcock, ruffed grouse, and yellow-shafted flicher. Ospreys have also been observed nesting in the area.

Reptiles and amphibians observed within this cover type are numerous and include northern water snakes, garter snakes, green snakes, snapping turtles, painted turtles, bullfrogs, green frogs, wood frogs, tree frogs, pickerel frogs, spring peepers, and red-spotted newts.

Various fish species also inhabit the marsh areas of the emergent wetland areas. These fish species include largemouth bass, red-fin pickerel, bluegill, pumpkinseed, yellow perch, green sunfish, creek chubsucker, brown bullhead, and golden shiner.

2.3.2.4 Aquatic Habitats

The aquatic habitats at the TOAR-FUDS overlap with the previous two cover types, scrub/shrub and emergent wetland habitat. Aquatic species listed for these two cover types are the same as those found in the TOAR-FUDS's aquatic habitats.

2.3.3 Species of Special Concern

There are numerous State and Federal endangered or threatened wildlife species in the Commonwealth of Pennsylvania as listed in Table 2-1. The list is from the Pennsylvania Game Commission. Not all species listed are resident in Monroe County.

Table 2-1
Endangered and Threatened Wildlife in Pennsylvania

Endangered	Threatened
Bald Eagle	Eastern Wood rat
Black Tern	Dickcissel
Least Shrew	Osprey
Indiana Bat	Sedge Wren
King Rail	Upland Sandpiper
Least Bittern	Small-Footed Myotis
Loggerhead Shrike	West Virginia Water Shrew
Peregrine Falcon	Yellow Bellied Flycatcher
Short Eared Owl	
Common Tern	
American Bittern	
Great Egret	
Yellow Crowned Night Heron	
Delmarva Fox Squirrel	

The Pennsylvania Game Commission has identified two species of special concern that have historically occurred and might presently occur within the project area. Osprey (*Pandion* *haliaetus*, PA Threatened), which inhabit lakes, marshes, rivers and swamps, have been confirmed nesting in the Oakes Swamp area near Powder Smoke Ridge. Also, northern water shrew (*Sorex palustris alibarbis*, PA At Risk), which inhabit mountain stream riparian areas, have been observed along Tobyhanna Creek near Warnertown on State Game Lands #127.

The U.S. Department of the Interior (DOI), Fish and Wildlife Service (USFWS), has identified two species of special concern within the TOAR-FUDS. The project site is located within the range of the federally threatened bald eagle (*Haliaeetus leucocephalus*). Bald eagles typically occur in the vicinity of aquatic ecosystems; they frequent lakes, reservoirs, large rivers, and wetland systems. Their nests are usually built in large trees within 2 miles of these features. Bald eagles are vulnerable to human disturbance, particularly during the nesting season.

The project site is also within the known range of the federally threatened bog turtle (C*lammy muhlenbergii*). Bog turtles inhabit shallow, spring-fed fens, sphagnum bogs, swamps, marshy meadows, and pastures characterized by soft, muddy bottoms; clear, cool, slow-flowing water, often forming a network of rivulets; high humidity; and an open canopy. Bog turtles usually occur in small, discrete populations occupying suitable wetland habitat dispersed along a watershed. The occupied "intermediate successional stage" wetland habitat is usually a mosaic of micro-habitats ranging from dry pockets, to areas that are saturated with water, to areas that are periodically flooded. Some wetlands occupied by bog turtles are located in agricultural areas that are subject to grazing by livestock.

The Bureau of Forestry also identified numerous plant species of special concern that might presently occur within the project area, as listed in Table 2-2. Not all species listed necessarily exist on site.

2.4 CURRENT AND PROJECTED LAND USE

The entire site is used for outdoor recreation, including hunting and fishing. There is no stated intent by either landowner (PGC or DCNR) to change the land use. Significant upgrades to infrastructure in the Park are planned for 2006. The major industries of the area are tourism and construction. The Tobyhanna Army Depot also employs a significant workforce in the support of its mission.

Table 2-2
Plant Species Tracked by Pennsylvania Natural Heritage Program within the TOAR-FUDS

Scientific Name	Common Name	State Status	Proposed State Status
Arceuthobium pusillum	Dwarf Mistletoe	PT	PT
Aster praealtus	Veiny-lined Aster	N	TU
Bidens discoidea	Small Beggar-ticks	N	PR
Carex disperma	Soft-leaved Sedge	PR	PR
Carex paupercula	Bog Sedge	PT	PR
Elymus trachycaulus	Slender Wheatgrass	N	TU
Gaultheria hispidula	Creeping Snowberry	PR	PR
Juncus filiformis	Thread Rush	PR	PR
Ledum groenlandicum	Common Labrador-tea	PR	PR
Lemna valdiviana	Pale Duckweed	PX	PX
Lonicera villosa	Mountain Fly Honeysuckle	PE	PE
Myrica gale	Sweet-gale	PT	PT
Myriophyllum farwellii	Farwell's Water-milfoil	PE	PE
Nuphar microphylla	Yellow Cowlily	TU	PE
Potamogeton oakesianus	Oakes' Pondweed	TU	PE
Sparganium androcladum	Branching Bur-reed	PE	PE
Sparganium augustifolium	Burr-reed	N	TU
Utricularia inflate	Floating Bladderwort	N	TU

PE = Pennsylvania Endangered
PT = Pennsylvania Threatened
PR = Pennsylvania Rare
PX = Pennsylvania Extirpated
PV = Pennsylvania Vulnerable
TU = Tentatively Undetermined
N = No current legal status exists, but is under review for future listing

2.5 DEMOGRAPHIC PROFILE

Monroe County, which contains the majority of the TOAR-FUDS, and Wayne County are the second and third fastest growing counties in the Commonwealth of Pennsylvania, respectively. Census data for Monroe and Wayne Counties are presented in Table 2-3. Part of the population growth is due to a growing transient weekend population, given the area's proximity to several major metropolitan areas and the extensive outdoor recreational opportunities available in the region.

Table 2-3
Census Data for Monroe and Wayne Counties[2]

County	Population			
	1970	1980	1990	2000
Monroe County	45,422	69,409	95,709	138,687
Wayne County	29,581	35,237	39,944	47,722

2.6 HISTORY

The TOAR-FUDS was composed of approximately 21,100 acres, consisting of firing points and impact areas. The Army originally leased the lands of the TOAR-FUDS in 1912 for the purpose of troop training. Later that year the Army formally acquired the lands. Both regular Army and National Guard field artillery units from throughout the Northeast and Mid-Atlantic states trained at Tobyhanna. During World War I, the reservation also served as a training center for tank and ambulance units.

In February 1919, the TOAR-FUDS received a mission to store trinitrotoluene (TNT) for the Army. Bunkers were created in the southwest artillery range (current game lands) and up to 4

[2] Data from http://www.censusscope.org.

million pounds of TNT were placed into storage[3]. Ten months later, in October 1919, the designation of being a Temporary Explosives Storage Depot was withdrawn and the TNT was removed from the TOAR-FUDS[4].

Prior to World War II, training was expanded to include cadets from the Army's Military Academy at West Point. Training reached its height during World War II with intensive artillery training being conducted. After the end of World War II, both the mission and activities of the artillery ranges were phased out.

In 1949, 14,000 acres were deeded to the Commonwealth of Pennsylvania's Game Commission. This land formed the basis for State Game Lands Number 127. The roads covered in this task order are covered in State Game Lands Number 127. Also in 1949, an additional 7,080 acres were deeded to the Commonwealth of Pennsylvania's Department of Forest and Waters. This land formed the basis for the Tobyhanna State Park.

On 15 September 1947, the United States Department of Defense (DOD) issued a Certificate of Clearance for the TOAR-FUDS. This certificate indicated that all lands within the Tobyhanna Military Reservation were given a ***visual inspection*** and found to be clear of all dangerous and/or explosive materials.

On 1 October 1952, the Commonwealth of Pennsylvania sold 1,418.49 acres of the area back to the U.S. Government. This tract of the original TOAR was required for the establishment and development of the Tobyhanna Signal Depot, which was officially commissioned on 1 February 1953 and remains active today, having been renamed the Tobyhanna Army Depot (TYAD).

Today, the Park covers the northeastern third of the site, currently contains minimal infrastructure, and is used for multiple recreational purposes, including camping, boating, swimming, hunting, fishing, hiking, snowmobiling, and mountain biking. Significant upgrades to

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[3] The Archives Search Report (ASR) contains two references to the amounts of TNT stored. One is the 4 million pounds cited above and believed to be correct, and the other is 40 million pounds. WESTON will continue to attempt to verify the correct amount of TNT stored.

[4] ASR, Paragraph 4 b (14), page 10.

infrastructure in the Park are planned for 2006. Game covers the remaining southwestern portion of the site and serves as a habitat for large and small game animals that are hunted in season, and features several lakes and streams that are fished regularly. The Pennsylvania Game Commission (PGC) uses some of the land in Game for food plots and timber sales.

Also, based on the known or potential presence of UXO throughout the TOAR-FUDS, emergency management agencies in Monroe and Wayne Counties have designated a no-fire suppression zone in all areas within 2,577 feet around the entire perimeter of the FUDS boundary. The no-fire suppression zone is shown on maps maintained by local fire departments.

2.7 PREVIOUS INVESTIGATIONS

Previous investigations conducted at the TOAR-FUDS are discussed in the following subsections.

2.7.1 USEPA EPIC Study

EPA's National Exposure Research Laboratory, through its Environmental Photographic Interpretation Center (EPIC), analyzes historical records such as aerial imagery, historic and thematic maps, and other cartographic data for environmental site analyses and civil and criminal actions.

Aerial imagery of the TOAR-FUDS was collected from between 1939 and 1999. The photographs are indexed in the EPIC film, and hard copies are currently maintained at WESTON.

2.7.2 ATSDR Public Health Assessment

The Agency for Toxic Substances and Disease Registry (ATSDR), established under the mandate of CERCLA, conducted a public health assessment (PHA) at TYAD. The results of the PHA were published in a report dated 6 May 1997. ATSDR's PHA focused on human exposure to contaminants. In the PHA, TYAD is discussed as three separate OUs and other areas of concern (AOCs). OU 1 consists of waste disposal AOCs 4 and 7 (also known as Areas A and B, respectively). OU 2 contains former electrical transformers. OU 3 includes two former hazardous waste facilities. The other AOCs discussed in the PHA include the inactive sanitary landfill, the Oakes Swamp disposal area, Barney's Lake/Hummler Run, and the TOAR-FUDS.

According to the PHA, the TOAR-FUDS is located both on- and off-post. The on-post ranges are patrolled and have warning signs posted. The on-post ranges are not a physical hazard. The off-post ranges are located in Park and Game. These ranges could pose a physical hazard to hunters and the public in Areas A and B.

2.7.3 Archives Search Report

In September 1995, USACE prepared an ASR for the TOAR-FUDS. The Rock Island District and Defense Ammunition Center and School prepared it for the USACE, Huntsville Engineering and Support Center (CEHNC) (USACE, 1995). The report contains two volumes of information. The first is a factual report of the findings, and the second contains the recommendations. WESTON was only able to review the findings volume.

The ASR summarizes the site, historical ordnance presence, site eligibility for the FUDS program, and results of a visual site inspection, and provides an evaluation of ordnance and other site hazards. In the preparation of the ASR, historical records were searched and site interviews conducted with numerous personnel. The results of the effort are contained in detail in the numerous appendices of the report.

The Archives Search Report (ASR) identified 8 main Firing Points (FPs) and 11 principal Target (Impact) Areas (TAs). FP Numbers 6 and 7 and TA Number 5 are on the current TYAD property. UXO issues on TYAD are identified as Operable Unit (OU) 4, and were addressed in an EE/CA for TYAD and a subsequent Record of Decision (ROD), and are not being further evaluated in this investigation. Figure 2-4 shows a small scale 1920s era range map, which was located in the Park Ranger’s office during a site visit. This map was used to validate other maps and known information on FPs and TAs at the TOAR-FUDS.

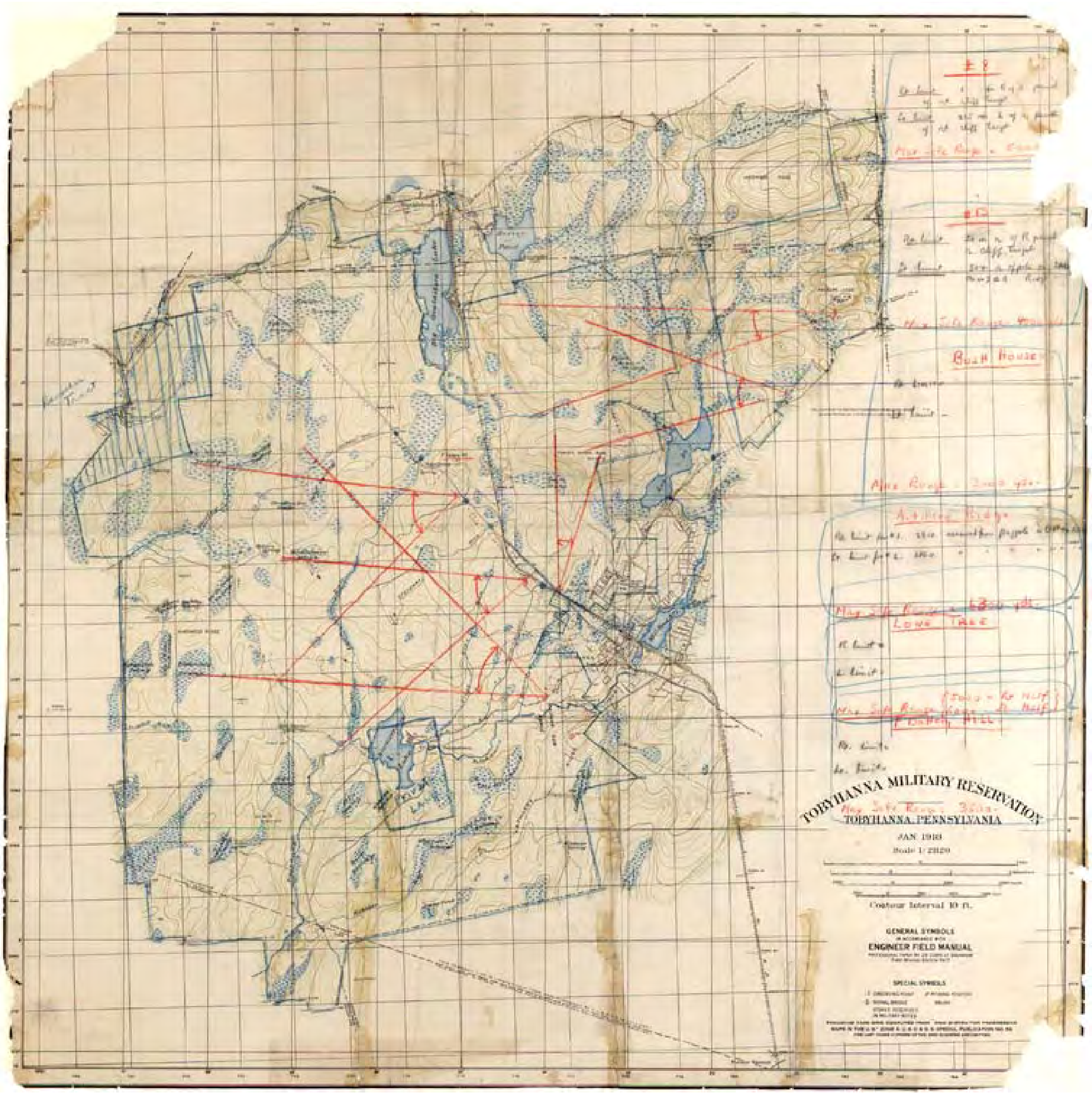


Figure 2-4 1920s Era Map of Tobyhanna Artillery Ranges

USACE uses Risk Assessment Code (RAC) procedures to prioritize Military Munitions Response (MMR) actions at FUDS sites. USACE guidance requires completion of the RAC during the development of the preliminary assessment phase for FUDS. The RAC score is derived from a risk assessment that evaluates two factors, hazard severity and hazard probability. The TOAR-FUDS has been rated as the highest USACE priority, with a score of RAC-1.

2.7.4 Previous Investigations for UXO

2.7.4.1 1998 HFA TCRA in Park

CEHNC contracted with Human Factors Applications (HFA), Contract DACA87-95-D-0027, Task Order 0017, issued 30 June 1997, to conduct a TCRA on several locations within the Park. All locations were within the boundaries of the Park and the areas included:

- Campgrounds (150 acres) to a depth of 2 feet (ft).
- A total of 10 miles of hiking trails to a depth of 1 ft. (the red, blue, and yellow trails).
- Beach Area (4.5 acres) to a depth of 1 ft.
- Day use picnic area (20 acres) to a depth of 1 ft.
- Youth camping area (9 acres) to a depth of 2 ft.
- Area near the boat ramp (4 acres) to a depth of 1 ft.

HFA conducted the TCRA in 1998 and issued two clearance reports, one covering the trails and campgrounds, and the other covering all remaining areas. The results of the TCRA are discussed in Subsection 4.1. UXO items found during the clearance are shown in Figure 4-1.

2.7.4.2 1998 HFA Construction Support at TYAD

CEHNC contracted again with HFA, Contract DACA87-95-D-0027, Task Order 0027, to provide construction support for a radar site on Powder Smoke Ridge at TYAD. HFA conducted on-site removal activities in 1998. The footprint of the construction site (approximately 20 acres) and an area 100 feet around the footprint were cleared to a depth of 4 feet. The planned fence line and fence line footprint were cleared to a depth of 4 feet. All other areas within the construction site were cleared to a depth of 1 foot. The results of the construction support project are discussed in Subsection 4.1. UXO items found during the clearance are shown in Figure 4-1.

2.7.4.3 2004 WESTON Surface Clearance at TYAD

CENAB contracted with WESTON, Contract DACA31-01-00-D-0023, Task Order 0049, to conduct a surface removal of UXO prior to tree clearing activities related to the radar facility on Powder Smoke Ridge at TYAD. WESTON conducted the surface removal in 2004 along the 150-feet-wide tree clearing zone outside the radar facility perimeter fence line and in areas adjacent to the tree clearing zone for access. The area totaled approximately ten (10) acres. The results of the construction support project are discussed in Subsection 4.1. UXO items found during the clearance are shown in Figure 4-1.

2.7.4.4 2004 WESTON Construction Support at TYAD

CENAB contracted with WESTON, Contract DACA31-01-00-D-0023, Task Order 0049, to provide construction support during geotechnical sampling at the proposed Training and Conference Center at TYAD. WESTON performed the construction support in 2004. The results of the construction support project are discussed in Subsection 4.1. No UXO items were identified on the ground surface or in the subsurface soils.

2.7.4.5 2004 WESTON TCRA in Game

The USACE, Baltimore District contracted WESTON in September 2003 to conduct a TCRA on two roads in the southwest artillery range, 7-Mile Road and Trail No. 1. WESTON conducted the TCRA in 2004. The results of the TCRA are discussed in Subsection 4.1. UXO items found during the clearance are shown in Figure 4-2.

3. SITE INVESTIGATION

This section provides an overview of the site characterization methodology, data collection, utilization, and application processes, as well as sampling parameters that were performed at the TOAR-FUDS for MEC and MC.

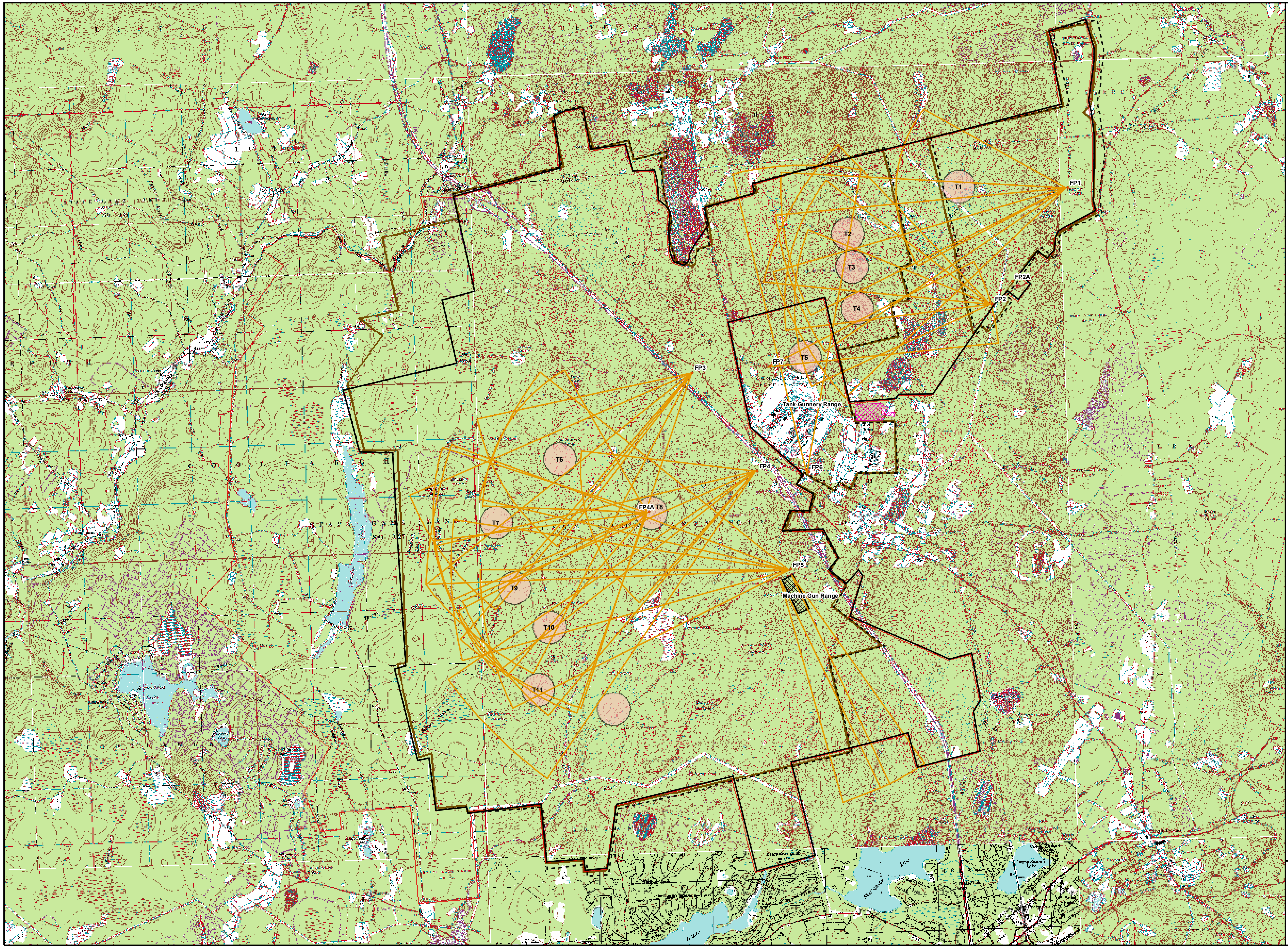
3.1 SITE INVESTIGATION FOR MUNITIONS AND EXPLOSIVES OF CONCERN

A combination of instrument-aided reconnaissance (IAR) and digital geophysical mapping (DGM) investigative methods were performed at the TOAR-FUDS to characterize the nature and extent of MEC at the site, validate and refine the CSM, and support risk-based selection of MEC response alternatives. This section describes the geophysical methods and procedures, intrusive results, the nature and extent of MEC presence, and environmental sampling results.

3.1.1 MEC Conceptual Site Model Input

The original CSM input parameters consisted of the ASR, site visits, a TCRA performed by USACE at the Park trails and camping areas, and interviews with Park personnel. In general, the primary sources of MEC-related material at an artillery range are associated with weapons training. Weapons training consists of FPs, TAs, and Range Safety Fans (RFs). Based on these typical range components, previous investigations, and the reports and finds of UXO to date, both the Park and the Game were divided into four AOIs: FPs, TAs, RFs, and Other Areas. The AOIs were developed based on the original CSM shown as Figure 3-1, which is also presented in Appendix I of the TOAR EE/CA Work Plan.

Other input parameters to the original CSM include “MEC release mechanisms” and “probable ordnance contamination by area.” The various release mechanisms associated with each primary source type (FPs, TAs, and RFs) are presented in Table 3-1. The most probable contamination by area for the TOAR is summarized in Table 3-2.



Legend

- 1932 Firing Points
- Range Fan
- 1932 Target Areas
- 1932 Boundary
- 1918 Boundary
- EPA Boundary

Base Map:
USGS Topographic Quadrangles
Blakeslee; Buck Hill Falls; Moscow;
Mount Pocono; Newfoundland; Pocono
Pines; Sterling; Thornhurst; Tobyhanna

N
W E
S

0 Miles

Figure 3-1
Original CSM For
TOAR - FUDS

T/Tobyhanna/mxds/RIFS_Draft/DRAFT_MARCH/LOriginal CSM for Former_Toar 3-1.mxd 062705

Table 3-1
MEC Release Mechanisms

MEC Activity	Primary Source	Primary Release Mechanisms	Expected MEC and Munitions Debris Contamination	Initial Contamination by MEC
Weapons Training	Firing Point	Loss or discard	Non-functioned munitions (DMM)	Ground surface
				Below grade
		Burning of excess propellant loss, burial or discard of propellant bags, disposal of dud munitions	Propellant residuals (MC)	Ground surface
				Sediment/soils
			Explosive residuals	Ground surface
				Sediments/soils
	Target Areas	Munitions firing, range maintenance/clearance activities	Fully functioned munitions (scrap)(MD)	Ground surface
				Below grade
			Partially functioned munitions (UXO)	Ground surface
				Below grade
			Failed to function munitions (UXO)	Ground surface
				Below grade
	Range Safety Fans	Munitions firing, range maintenance/clearance activities	Fully functioned munitions (scrap)(MD)	Ground surface
				Below grade
			Partially functioned munitions (UXO)	Ground surface
				Below grade
			Failed to function munitions (UXO)	Ground surface
				Below grade

Table 3-2
Probable Ordnance Contamination by Area

AREA	MOST PROBABLE CONTAMINATION
Firing Points	Discarded military munitions (DMM), propellants, burn areas
Machine Gun Range	Small Arms – Complete and component
Target #1 (Park)	75-mm and 155-mm projectiles and components; targets; MPPEH
Target #2 (Park)	37-mm, 75-mm, and 155-mm projectiles and components; targets; MPPEH
Target #3 (Park)	37-mm, 75-mm, and 155-mm projectiles and components; targets; MPPEH
Target #4 (Park)	37-mm, 75-mm, and 155-mm projectiles and components; targets; MPPEH
Target #5 (TYAD)	37-mm projectiles and components
Target #6 (Game)	75-mm and 155-mm projectiles and components, targets, MPPEH
Target #7 (Game)	75-mm and 155-mm projectiles and components, targets, MPPEH
Target #8 (Game)	75-mm and 155-mm projectiles and components, targets, MPPEH
Target #9 (Game)	75-mm and 155-mm projectiles and components, targets, MPPEH
Target #10 (Game)	75-mm and 155-mm projectiles and components, targets, MPPEH
Target #11 (Game)	75-mm and 155-mm projectiles and components, targets, MPPEH

In August 2004, based on preliminary data collected during the site investigation (through IARs, DGM, and the TCRA along 7-Mile Road and Jeep Trail #1), the CSM map was amended to reflect known site conditions. The amended maps for the Park and the Game are shown in Figures 3-2 and 3-3, respectively. The major changes made to the original CSM included the combination of TAs #2, #3, and #4 into one TA, the enlargement of TA #8 to include items found to the west, and the presence of FP #2a.

3.1.1.1 UXO Estimator Module 1 Input

The site characterization methodology for TOAR is described in Subsection 3.3.1.2 of the Work Plan. However, based on the field work and site data development and analysis, the site characterization methodology deviated from the Work Plan by achieving the characterization with less investigative acreage than originally planned. Therefore, the number of acres to be investigated, summarized in Table 3-1 of the Work Plan, was reduced.

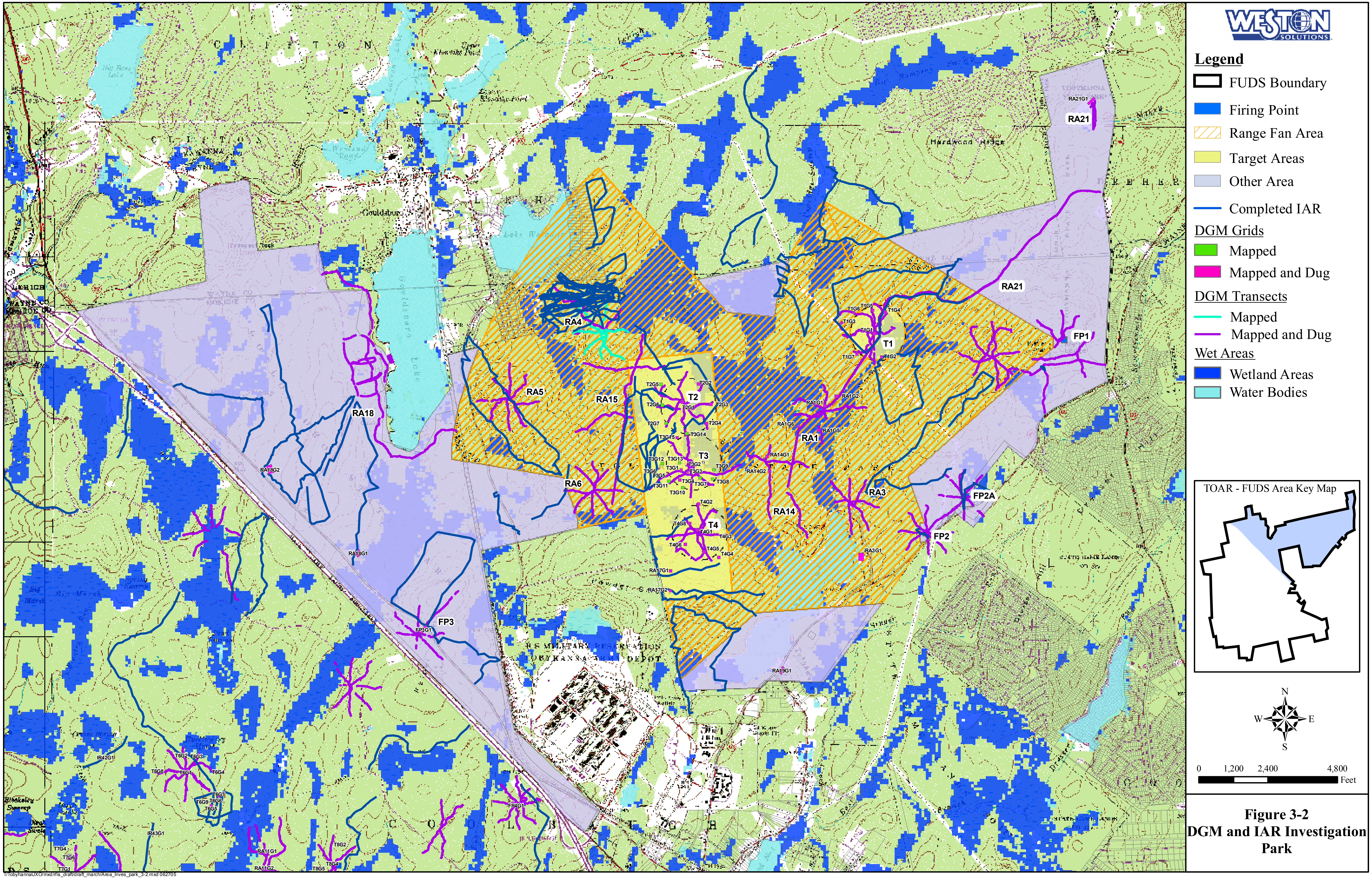


Figure 3-2
DGM and IAR Investigation
Park

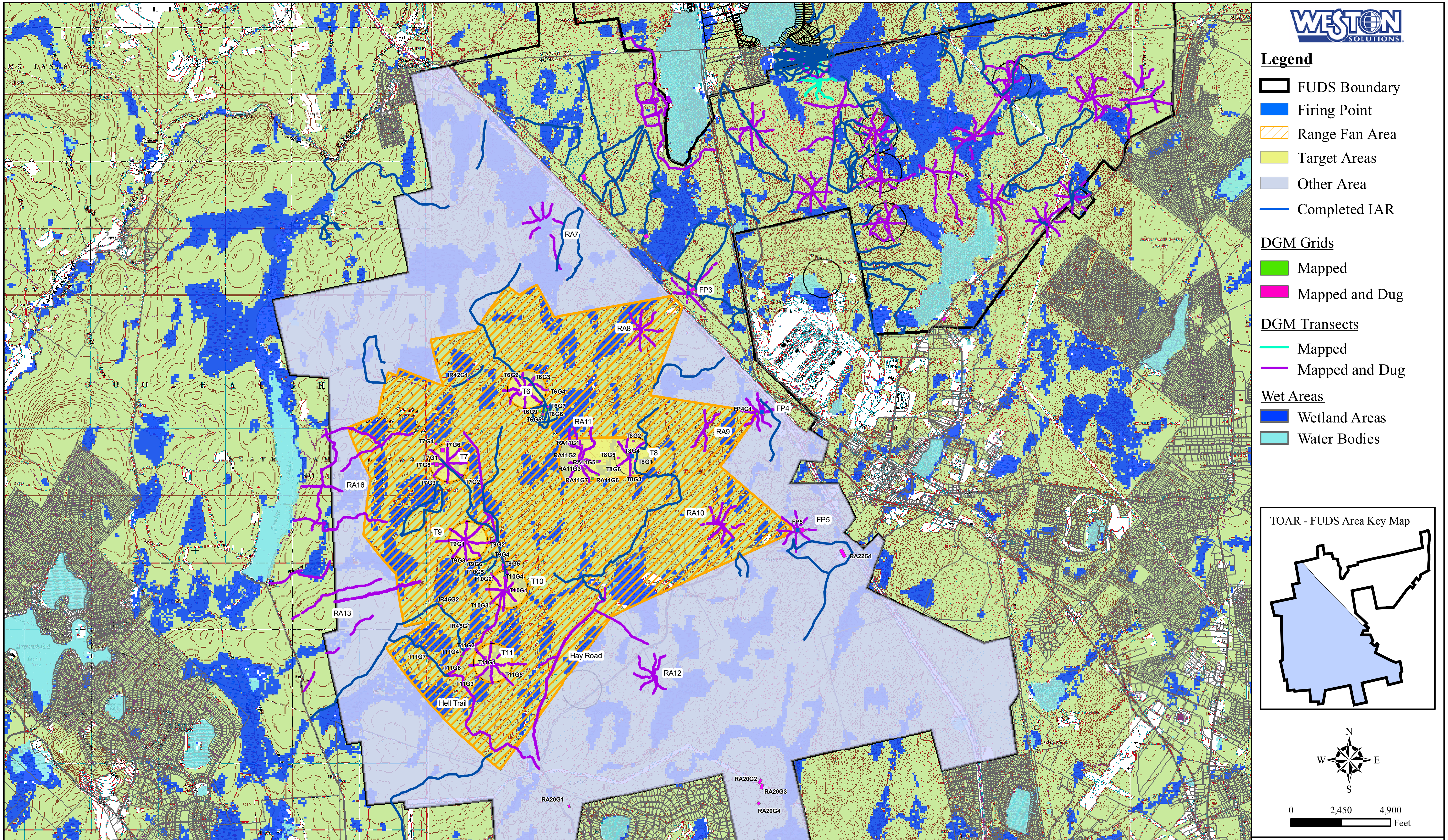


Figure 3-3
DGM and IAR Investigation Game

To accurately calculate a revised number of acres to be investigated, UXO Estimator, a statistical analysis tool developed by CEHNC, was applied. Specifically, UXO Estimator Module 1 was used to determine the number of acres to be investigated using DGM methods to locate anomalies that were probable munitions within the RFs, TAs, and Other Areas. All anomalies that were determined to be probable munitions were dug and any UXO found was tallied in its respective AOI. UXO Estimator was not applied to FPs because of their small area, geographical settings, and the probable manner in which MEC would have been historically disposed of in the vicinity of the FPs. Some FPs have little area where munitions could be buried due to shallow bedrock. It was decided that a more intensive investigation directed at probable areas where munitions could be buried was more appropriate at most FPs than statistical sampling. The intensive investigation at the FPs included the use of DGM transects and grids, IAR, "mag and dig" (M&D), and test trenching methods. This subsection discusses the use of UXO Estimator Module 1 as applied to TOAR, and its results.

3.1.1.1.1 UXO Estimator

UXO Estimator is a statistical analysis tool based on a negative binomial probability distribution. The negative binomial depends on only two outcomes: (1) success, meaning that the randomly placed UXO is in the investigated region (occurs with a probability "p"), and (2) failure, meaning that the UXO is not in the investigated region (occurs with a probability "q = 1-p"). The model assumed that there is a uniform probability of the occurrence of UXO across the site; however, the model also assumes that the UXO has been randomly deposited across the site. This means that there is an equal likelihood for UXO to fall anywhere within the sector; however, there is not necessarily a uniform distribution of UXO. There are three modules in the UXO Estimator Program:

- Module 1: Develop a Sampling Plan.
- Module 2: Analyze Field Data.
- Module 3: Unit Conversion.

3.1.1.1.2 UXO Estimator Module 1 as Applied to TOAR

Module 1 was used to calculate the minimum number of acres to be investigated at TOAR. Module 1 requires three input values:

- Size of AOI (in acres) – The total size of the area to be investigated.
- Target density – An assumed level of UXO presence throughout the AOI, normally stated as UXO per acre. The guidelines used for the target density are based on public usage and are as follows:
  - 0.1 UXO/acre when public usage of the AOI is significant (e.g., residential housing developments or schools).
  - 0.5 UXO/acre when public usage of the AOI is moderate or intermittent (e.g., recreational uses such as camping, hiking or hunting).
  - 1.0 UXO/acre when public usage of the land is minor (e.g., remote locations, agricultural tracts).
- Confidence level – The degree to which a calculated statistic meets or compares to some measure, such as target density. The default value is 0.95 (or 95%).

A target density of 0.5 UXO/acre was used for the entire site, along with the default confidence level of 0.95 (or 95%). UXO Estimator calculated that assuming no UXO is found, a minimum of 6 acres must be investigated in the RFs, TAs, and Other Areas to achieve a 95% confidence level for each area based on the target density of 0.5 UXO/acre, as summarized in Table 3-3. If UXO is found, additional investigation is required to meet the confidence level for the target density.

3.1.2 Instrumentation

A site-specific geophysical prove-out was conducted in January 2004 to identify the most effective equipment and methods to be used during the full-scale DGM activities (WESTON, 2004a [Work Plan Appendix K]). A subsequent detailed prove-out memorandum was submitted prior to DGM field work (WESTON, 2004a [Memorandum dated 21 April 2004]). Both documents are provided in Appendix D. WESTON demonstrated various positioning methods using both electromagnetic (EM) and magnetic geophysical sensors in combination with conventional, GPS, and ultrasonic (Ultrasonic Ranging and Data System [USRADS]) navigation

Table 3-3
Minimum Areas to be Investigated at TOAR-FUDS as Calculated by UXO Estimator Module 1

Areas	UXO Estimator Input			UXO Estimator Output
	Approx. Acres	Target Density	% Confidence	Minimum No. of Acres to Be Investigated[1]
State Park				
Range Fans	3,325	0.5	95	6
Target Areas	586			6
Other Areas	4,409			6
State Game Lands				
Range Fans	5,147	0.5	95	6
Target Areas	1,375			6
Other Areas	6,258			6

[1]Minimum acres calculated by UXO Estimator based on area, target density, and % confidence.

instrumentation. The compliment of geophysical methods assessed was based on the diverse and varying site conditions, vegetation, and terrain existing at TOAR.

The results from the prove-out demonstrated that a combination of the Geonics EM61-MK2 and Geometrics G-858 Cesium Vapor Magnetometer (in gradiometer configuration) integrated with real-time kinematic (RTK) GPS and USRADS positioning, respectively, should be the preferred geophysical instrumentation. The rationale was to use the MK2 with the RTK in open areas and the G858 with the USRADS in the wooded areas. However, based on site conditions, topography, terrain, tree canopy, and ergonomics, the G858 gradiometer integrated with the USRADS navigation proved to be the most effective instrumentation for DGM activities. In addition to the G-858 gradiometer, the Schonstedt Magnetic Locator also indicated acceptable performance during the GPO and was used for M&D investigation of a limited number of grids in rough terrain, reacquisition of DGM anomalies, and as a screening and avoidance tool by UXO-qualified personnel.

3.1.2.1 MAG Gradiometer

The magnetometer (MAG) survey was accomplished utilizing a Geometrics G-858 Cesium Vapor magnetometer/gradiometer in the vertical gradient configuration. The battery-operated G-

858 operates on a self-oscillating, split-beam, cesium vapor principle from which a signal proportional to the intensity of the ambient magnetic field is derived. Two sensors were mounted vertically on a staff at a separation and distance from the ground surface of approximately 3.0 ft (0.9 m) and 1.0 ft (0.3 m), respectively. The difference between the two sensor readings divided by the sensor separation was recorded as the magnetic gradient in units of nanoTeslas per meter (nT/m) at the measured location. Total field magnetometer data in units of nT/m were digitally stored in an instrument console at rates of 10 times per second for subsequent download to a computer, diurnal correction, and post processing.

DGM transects were conducted using the G-858 gradiometer integrated with the Trimble Pro XRS GPS, as described in subsection 3.1.5.2.1. The integrated Trimble Pro XRS GPS has a real-time synchronous clock, whereby a timestamp is exported with the total field MAG data. Therefore, a diurnal correction was applied to the top and bottom sensors of the DGM transect total field data. DGM grids were conducted using the G-858 gradiometer integrated with USRADS navigation system, as described in subsection 3.1.5.2.2. The integrated USRADS positioning system does not have a real-time synchronous clock, and subsequently no exportable timestamp. Therefore, a diurnal correction was not applied to the DGM grid total field data.

3.1.2.2 MAG Base Station

Diurnal variations in the Earth's magnetic field were monitored and recorded at a base station utilizing a Geometrics G-856AX portable magnetometer. The battery-operated G-856AX utilizes proton precession technology and contains a sensor mounted on a staff. Data in nT units were stored digitally at a rate of 3 readings per minute (every 20 seconds) in an instrument console for subsequent download to a computer and correction of the G-858 data, if appropriate, as described in subsection 3.1.2.1 above.

3.1.2.3 Schonstedt Magnetic Locator

Schonstedt magnetic locators detect ferrous metal materials. The Schonstedt is a hand-held unit that detects changes in the Earth's ambient magnetic field caused by ferrous metal. The technology utilizes two fluxgate sensors mounted a fixed distance apart and aligned in gradiometer configuration to eliminate a response to the Earth's ambient field. The magnetic locators generate an audio output and a meter deflection when either of the two sensors is exposed to a disturbance of the Earth's ambient field associated with a ferrous target and/or the presence of a permanent field associated with a ferrous target. Schonstedt detectors were used for "M&D" clearance of a limited number of grids in rough terrain, reacquisition of DGM anomalies, IAR surveys, and as a screening and avoidance tool by UXO-qualified personnel. Schonstedt detectors were checked and tested at the GPO grid each day they were used. Documentation of these checks is included in the quality control (QC) log provided in Appendix E.

3.1.2.4 Navigation and Mapping System

Navigation equipment used in surveying activities on the project were hand-held GPS (Garmin, eTrex Legend), differential GPS (DGPS) (Trimble Pro XRS) and ultrasonic ranging and data system units (CHEMRAD USRADS).

For IAR surveys and navigation throughout the study area, the light-weight Garmin hand-held GPS was used to position UXO items and log ground coverage to accuracies of approximately ± 3 meters, depending on tree canopy and satellite configuration. The battery powered eTrex Legend was Wide Area Augmentation System (WAAS)-enabled allowing for improved accuracy over traditional hand-held devices.

For transect DGM, the G858 was integrated with DGPS (i.e., Trimble Pro XRS) to sub-meter accuracy in most areas. However, in areas of heavy tree canopy or loss of sufficient satellite constellation, DGPS positioning may have exceeded the demonstrated sub-meter accuracy. Specifically, four DGPS accuracy tests were performed during DGM transect data acquisition in areas adjacent to known survey monuments. The monument locations are located at FP4, FP5, T8 and T9 (Hell Trail) and had a monument to DGM target offset of 2.5 ft, 2.1 ft, 0.7 ft and 2.9 ft, respectively. The Trimble Pro XRS system, which includes an integrated GPS receiver and radio receiver, was used, rather than a sub-centimeter RTK GPS system because it was more functional in the rough site conditions (thick tree canopy and varying topographic conditions) at the Park and Game. The Trimble Pro XRS system was also used for reconnaissance of DGM grid locations, navigating throughout the study area, IAR surveys, and logging environmental sample and test pit locations.

For focused DGM grids and one transect in the Game, WESTON used the CHEMRAD USRADS navigation system. USRADS is a real-time location and positioning system that was created to provide an ultrasonic location system for DGM in areas not suitable for use of GPS systems. Such areas are typically under vegetation canopy, in deeply dissected terrain, around structures and inside buildings. The USRADS employs three different technologies: ultrasonics, radio frequency (RF) transmission and microcomputers. An ultrasonic signal is emitted from the Ultrasonic Transducer (called the crystal), which was mounted over the top MAG sensor staff (at an offset distance of 0.1 meters from the center point of the MAG sensor), and connected to a portable Data Pack worn by the geophysicist. The receiver within the Data Pack captured real-time positions and total field data from the top and bottom sensors from fixed-point stationary receivers and transmitted telemetry data to a master controller. Data were then interfaced real-time at 1-second intervals from the Master Controller to a portable computer for real-time viewing, storage, and analysis. In addition to collecting DGM data, the USRADS system was utilized to reacquire DGM anomalies.

All grid corners were surveyed by Prudent Engineering, LLP (based out of Syracuse, NY), a professional surveyor licensed in the Commonwealth of Pennsylvania. Prior to the start of DGM activities (30 March to 15 April 2004), a total of 16 permanent control monuments (bronze) were established at TAs and FPs in the Park and Game lands. Prudent Engineering performed the horizontal and vertical control of the monuments to the “Class I Third Order” and met the requirements of USACE DID OE-005-07.01. Navigational and monument data are presented in Universal Transverse Mercator (UTM), Zone 18, NAD83 coordinates in U.S. Survey Feet (us ft) units. The DGM grid corner survey and monument data are presented in Appendix F.

3.1.3 Quality Control of Geophysical Instruments

The geophysical field crews performed and recorded the following QC tests for the G858 gradiometers on a daily basis:

- *Static background* test twice daily (beginning and end of day) to record background response for 3 minutes at the “QC stand” to determine whether drift, interference, or equipment malfunction was occurring throughout the day.

- *Static spike* test twice daily (beginning and end of day) to record instrument response over a standard QC item (trailer ball) for 3 minutes.

- *Cable connection* test twice daily to check for loose or damaged connectors and cables.

- *Latency* test conducted within a DGM grid by placing a small length of rebar at the midpoint of a traverse and then traversing over the QC object with the G858 integrated with the USRADS three times in the direction that the data were to be collected (up/down/up). DGM transect latency was determined by traversing over a known survey monument (where available) with the G858 integrated with the Trimble Pro XRS in two directions.

- *Repeat line* tests conducted within each DGM grid by traversing a known transect (typically the eastern base line) the length of the grid twice in the same direction. DGM transect repeat lines were conducted at the QC base station prior to data collection over a known location and transect length (50 ft). This controlled setting enabled the Project Geophysicist to monitor the repeatability of the geophysical equipment.

- *QC seeds* installed at the four corners of each DGM grid. These seed items were known survey spikes installed by professional land surveyors. Typically the southwest (SW) corner was identified on the "data processing notes" as the seed item, which contained the offset distance from the spike and the offset direction. The response and location from the QC item within each survey grid provided QC of both instrument functionality and data positioning.

All QC test data were reviewed real-time prior to and subsequent to data collection and then placed in a database. Each piece of equipment was monitored over the life of the project for deviations. This ensured that the geophysical equipment was functioning properly. The data were reviewed by the Site Geophysicist and approved by the Project Geophysicist. If the data revealed a problem with a piece of equipment or a field operation, the data was reevaluated and, if necessary, the problem was corrected or the equipment was replaced.

3.1.4 Quality Assurance

Quality assurance (QA) was conducted by CENAB by implementing a QA Plan (CENAB, 2004) that was developed for the project, which is provided in Appendix G. The QA activities included USACE oversight and verification of UXO safety, DGM, anomaly excavation within grids, explosives inventory and storage, verification and certification of Ammunition, Explosives and

Dangerous Articles (AEDA), contractor QC activities, and coordination/consultation with PADEP personnel.

The CENAB UXO Safety Specialist and/or Geophysicist performed QA in the field on select grids to verify instrument response and reacquisition of anomalies. QA was achieved by planting a seed item (typically, a ½-inch diameter steel rod, approximately 8 inches long) by a CENAB representative within a grid. Per CENAB, eight QA seeds were planted. Seed items buried within grids intrusively investigated were recovered during the investigation as part of anomaly excavation activities by the WESTON dig team.

The intent of the DGM QA program was to examine each data set submitted with a focus on the QC metrics provided by WESTON. The intent of the review was to verify that equipment was operating within specifications; that background noise conditions and indications of data collection and interpretation procedures appeared consistent; that the data produced appeared reasonable; and that the data submittal was complete. More intensive reviews of the geophysical data were performed by CENAB on an as-needed basis.

3.1.5 Geophysical Survey

The geophysical mapping effort was conducted at the TOAR-FUDS between April 19 and October 14, 2004. The mapping effort includes data collected from four sources: IAR, DGM transects, DGM grids, and M&D. A total of 354 acres were investigated throughout TOAR, including the TCRA along 7-Mile Road and Jeep Trail #1. The TCRA, contracted separately to WESTON by CENAB, totaled 26.9 acres. A total of 61 acres were digitally geophysically mapped utilizing grids and transects. The locations of the investigated areas are shown in Figures 3-2 and 3-3 for Park and Game, respectively. The original Survey Mission Plan Map, as detailed in the approved project Work Plan in Appendix B, Map 4, lays out the sampling plan for DGM grids and transects. The selection/location process of the IAR and DGM coverage was dynamic and involved a number of factors including statistical validity, representative coverage, biased sampling, and project team input. Locations were adjusted in the field taking into consideration terrain, vegetation conditions, health and safety (H&S), and new information obtained as part of the study. Weekly updates including DGM methods, area locations, and intrusive anomaly findings were submitted to the project team (CENAB, PADEP, and

WESTON) for feedback to the field team. Site characterization field work was adjusted based on feedback. In particular, CENAB suggested long, linear DGM transects at certain areas, in addition to the prescribed azimuthal pattern. In addition, data processing techniques were discussed between WESTON and CENAB to ensure high quality data were acquired.

Geophysical data were used to characterize the site while assessing the validity of the CSM and provided distribution and density information on potential UXO items throughout the study area.

3.1.5.1 Instrument-Aided Reconnaissance (IAR)

IAR is a systematic search that uses qualified UXO technicians to search for and collect data or evidence of military or UXO activities in an area. This method of reconnaissance enabled teams of qualified UXO technicians to cover a wide area in an efficient and expedient manner. IAR also enabled coverage in hard to reach areas that were unfavorable to DGM and survey equipment and manpower. The IAR focused on areas outside firing fans as identified in the CSM, areas that possess very little or no evidence of military UXO activities, areas inaccessible to DGM activities, and personal accounts from landowners and local agencies. IAR data was also used to assist in placing DGM transects and grids, particularly in areas where UXO or MD was recovered. For example, in Game, as shown in Figure 3-3, IAR data was used to place DGM grids T6G5, T6G6, T6G7, and T6G9 immediately southeast of Target #6, DGM grids IR45G1 and IR45G2 southwest of Target #10, and DGM grid IR42G1 northwest of Target #6. In Park, as shown in Figure 3-2, IAR data was used to place DGM grids RA17G1 and RA17G2 southwest of Target #4 on Powder Smoke Ridge near the TYAD, and a DGM transect running west of Targets #2 and #3 in RA15.

Teams of at least two UXO-qualified personnel performed the IARs. These teams were equipped with site maps, hand-held magnetometers, a digital camera, a handheld GPS unit, and a PDA with UXOFast^{SM} for recording observations. The magnetometer was used for safety and to assist in searching for military or MEC-related materials. The magnetometer was swung from side to side by a team member, using one hand, as the team advanced. Hand-held GPS receivers (Garmin eTrex Legend) were used to record reconnaissance paths and surface or multiple subsurface contact data that were encountered during the reconnaissance. When the team advanced approximately 50 meters without recording any data, a GPS location was taken and recorded to allow their path to be entered in the project geographic information system (GIS). UXOFast[SM] was the integrating data management and collection platform for the IAR. Photos were taken of items of concern or unusual features. A photo log is provided in Appendix H.

IAR is not a DGM transect and the locations of all subsurface anomalies were not marked, and in some instances, excavation of anomalies did not occur during the ground reconnaissance. However, when the UXO Technician believed (in his professional judgment) that a subsurface anomaly warranted investigation [due to factors such as magnitude of the magnetometer's response, visual observation of surface features that indicate potential UXO (fragments, craters, MPPEH), density of magnetometer responses to subsurface anomalies, etc.], he had the authority to excavate the item. Items selected for excavation were photographed, positions recorded, and identification of the item logged for transfer to the project GIS. When identified as an UXO, the UXO Technician immediately notified the Senior UXO Supervisor (SUXOS) to arrange for disposal.

Overall, because there were very few items encountered due to the many background areas traversed, when a subsurface anomaly was encountered, the object was excavated, logged and located. Also, the area covered by the reconnaissance path was calculated as the distance traveled multiplied by the width of the approximate 10-ft footprint per IAR team member. The 10-ft footprint assumed for each IAR team member was based on the length of the magnetometer, the radius of the arm swing of each team member, and the fact that visual searching was conducted concurrently by each team member.

3.1.5.2 Digital Geophysical Mapping (DGM)

A combination of grids and transects were used to maximize the area covered by the DGM. Grids were used to quantify types and densities of potential UXO contamination, and transects were used to determine the horizontal extents of contamination.

3.1.5.2.1 DGM Transects

The DGM transects were conducted using the G858 gradiometer integrated with the Trimble Pro XRS GPS to record navigational information defining the paths selected by the project team.

Survey activities were conducted by shoulder-carrying the G858 gradiometer for the collection of the geophysical data (10 readings per second) while integrating in real-time the continuously recorded location information (1 reading per second). An UXO Technician provided visual surface UXO clearance and brush-cutting ahead of the geophysical technician's navigated path. Predetermined navigational waypoints were loaded in the GPS and followed to assist in navigating through the woods and heavy brush. The nominal spacing of each transect was 1,000 ft, but was field-adapted based on terrain considerations: if the terrain were open or a path followed, the transect went beyond 1,000 ft; if the terrain prohibited data collection in a safe manner, the transect ended or deviated from the planned route.

The area covered by the transects was calculated as the distance traveled multiplied by the approximate width of the geophysical instrument footprint. Data collected along DGM transects were reviewed to calculate appropriate footprints for DGM transects. The width of transects in areas where 37-mm UXO were recovered was conservatively estimated to be 3 feet, based on the detection radius for 37-mm UXO. The width of transects in all other areas was conservatively estimated to be 5.33 feet, based on the detection radius for 75-mm UXO. Any UXO/MPPEH items encountered on the surface while traversing the DGM transect were logged in a PDA with a GPS location for subsequent download into UXOFast℠. This enabled the UXO team to navigate to the object for further UXO identification and final disposition.

One cluster of transects located in the Game area (RA13 area in Figure 3-3) encountered heavy tree canopy that precluded the use of the Trimble Pro XRS GPS. The tree canopy intermittently blocked the GPS receiver satellite reception rendering the GPS ineffective. These transects were collected using the USRADS navigation system. This method proved very effective along the approximate by 4,000-foot traverse. With the USRADS positioning in place, multiple transects were collected along the whole transect length, yielding an effective transect width of approximately 20 ft (instead of the nominal 3 ft width per transect). However, the task was time consuming and had to utilize the surveyor services. The surveyor effort took approximately 1 week total; 2 days to bring in control to the RA13 area, and approximately 3 days to set control points along the 4,000-ft transect. Approximately 28 total acres of DGM transects were collected at both the Park and Game.

3.1.5.2.2 DGM Grids

The DGM grids were conducted by first establishing the general location within a FP, TA or reconnaissance area (RA). The term RA was defined in the field to describe areas of the site to be investigated that were not associated with FPs or TAs. That is, RAs were within RFs and Other Areas. Once the general location of the DGM grids were established, the licensed surveyor set four grid corners at a typical size of 100 ft x 100 ft (some grids had a nominal size of 50 ft x 50 ft, or 200 ft x 200 ft, depending on surface UXO contamination). A brush-clearing crew was then mobilized to clear enough vegetation, small diameter trees (<3 in) and dead-fall to facilitate and improve DGM conditions. DGM was then commenced using the G858 integrated with the USRADS navigation unit. Data were collected in relatively parallel lines and viewed in real-time to monitor a line spacing of less than or equal to 3 ft (generally, the DGM mapping team strived for an approximate line spacing of 2 ft) and to ensure quality data prior to demobilization off the grid. Data were also collected outside the surveyed grid boundaries to ensure quality target picking on the borders of the grid. The USRADS navigation system enables the data to be collected around trees, boulders, craters and other obstructions without affecting the integrity of the gradiometer data and yet maintaining very accurate positioning.

Prior to collecting geophysical data in the field, the Geophysical Team entered pertinent field data onto a Field Data Sheet as per Attachment A of the USACE Data Item Description (DID) OE-005-05.01. Entered data included, but was not limited to team name, file names, terrain and weather conditions, and a site sketch with annotations/obstructions.

Geophysical data were recorded on a field laptop computer in real-time at a rate of 10 samples per second. The data were referenced to the surveyed corner coordinates of UTM, Zone 18, NAD83 coordinates in U.S. Survey Feet units. Data were checked for completeness in the field; if a transect gap was evident, data were collected to fill-in the traverse. The raw data were then backed-up for archival and further processing. Approximately 33 acres (96 grids) were digitally geophysically mapped in the Park and Game using the G858/USRADS survey method.

All aspects of the DGM data collection process were accompanied by a qualified UXO Technician. UXO/MPPEH items discovered during these processes were logged via the UXOFast^{SM} system and appropriate actions were taken to reconcile the item.

3.1.5.3 Mag and Dig

In addition to the DGM grid survey techniques, a M&D method was also used during the site characterization. The M&D method was used in grid areas of unusually rough terrain and brush; those grids were located at FP3 (one grid at 200 ft x 200 ft) and the RA1 area (4 grids at 100 ft x 100 ft each) of Park. A Schonstedt magnetic locator was the geophysical equipment used to locate subsurface ferrous anomalies. The method involved UXO Technicians sweeping the entire surveyed grid in 5-ft lanes and placing a pin flag at each location where a ferrous anomaly was detected. The items were then excavated and logged on dig sheets for subsequent data input. Approximately 2 acres were intrusively investigated using this survey technique.

3.1.6 Anomaly Identification

3.1.6.1 Data Processing

At the end of each day, the raw geophysical field data were downloaded from data loggers and field laptops to a central geophysical data processing computer set up on-site. The downloaded data files (daily QC tests, latency and repeat tests and geophysical surveys) were imported into manufacturer-supplied software programs (Geometrics Magmapper 2000, USRADS Survey and Analyze and Microsoft's Excel) for pre-processing. For the full-scale mapping effort, the Site Geophysicist post-processed the field data using Geosoft Oasis Montaj™ software. The final processed DGM grid maps for the Park and Game land are presented in Appendix I. The format for the grid map presentation follows DID OE-005-05.01 Attachment D. QC checks on the data were also performed using Oasis Montaj™ and Excel software. The data processing steps are summarized as follows:

1. Import all DGM grid data from USRADS Analyze program along with "timestamp" data file into Oasis Montaj™ UX-Detect (top sensor, bottom sensor and vertical gradient).

2. Check data for spikes and dropouts. Run "DROPOUT.gs" (in-house script), and then dummy zero values.

3. Check timestamp column to ensure no duplicate values.

4. Set coordinate system for Easting/Northing.

5. Apply latency to the data using time channel.
6. Apply drift correction GX, UXDRIFT using 40, 40, 120 parameters.
7. Run the MAGDATAProcess.gs (in-house script to create map).
8. Fill out all necessary entries in data processing notes (in-house Access datasheet).
9. Grid the initial mag data with a 0.25 grid cell size and a 1.5-ft blanking distance.
10. Check data for chevron patterns. Adjust latency if necessary.
11. Create Analytic Signal (AS) grid.

The DGM transect data was pre-processed using Magmapper 2000 to obtain an XYZ file and did not utilize the USRADS Analyze program. Subsequent to the data processing steps outlined, a review of the data and the field data sheets was conducted, anomalies were identified and target picks were made.

3.1.6.2 Anomaly Selection and Ranking

The target picks were compiled into a dig sheet through an anomaly selection process. The Geosoft Oasis Montaj™ UX-Detect software was used as the DGM processing platform. The anomaly selection process involved the following steps:

1. Initial target selection. The initial AS value of 12 nT/US ft was used as the cut-off threshold based on the GPO results. Subsequent to 10 August 2004, the threshold was raised, based on dig data, to 25 nT/US ft with CENAB approval.
2. Automated target parameters include:
   a. Blakely test
   b. Smoothing filter of 3
   c. Peak detection level of 4
3. Perform a manual review of all targets for validity:
   a. Remove targets outside grid
   b. Dummy out known operator and equipment-induced targets
   c. Combine magnetic dipoles to a single target

   d. Select appropriate targets

4. Run "target search Radius" Access program to select maximum AS nT/US ft response within a 2-ft radius of target.
5. Add additional QA picks at/or below the cut-off threshold.
6. Finalize target selection after QC check by the Project Geophysicist and create dig sheet with accompanied map.
7. Upload to UXOFast^{SM} for reacquisition via PDAs.

A graphical representation of the DGM target data analysis flow is presented in Figure 3-4.

Initially, the anomaly targets were based on a cut-off threshold of 12 nT/US ft and depending on the number of anomalies in the grids, only a select number of targets were chosen for excavation. After discussions with CENAB and CEHNC on 10 June, 2004, the target lists for the DGM grids were divided into five AS amplitude groups, and then 50% of each amplitude group was to be excavated. Also, WESTON implemented a priority ranking system to be used for the DGM reacquisition teams. This priority rank and an analytic signal value enabled the dig team to verify in the field whether the dug item agreed with the geophysical data. The target priorities consist of the following ranks:

- Priority 1 = Characteristics indicative of buried metal.
- Priority 2 = Signal above higher background levels.
- Priority 3 = Low signal to background levels, suspect targets, possibly operator or geology induced.
- Priority 4 = QA picks at/or below the cut-off threshold

At the end of July, the target pick and reacquisition strategy of DGM anomalies changed to reflect the introduction of UXO Estimator by CENAB, which is a tool to statistically estimate UXO density and was not included in the original work plan. Instead of the reacquiring 50% of

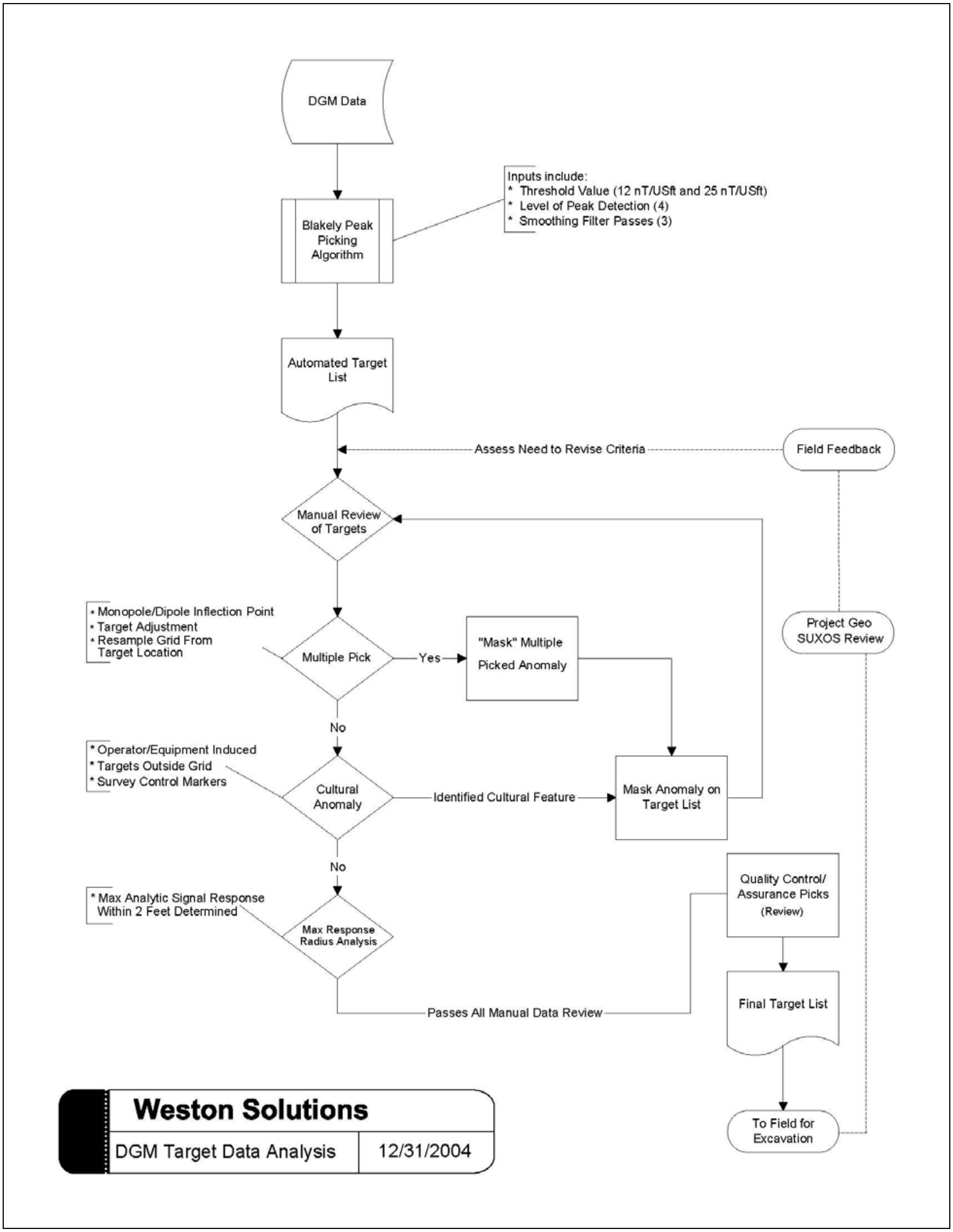


Figure 3-4 DGM Target Data Analysis Flowchart

the 5 amplitude categories strategy, the new implemented strategy called for all the anomalies greater than the cut-off threshold of 12 nT/ft to be reacquired for excavation. On 10 August 2004, WESTON/PADEP recommended the cut-off threshold be raised, based on dig data, to 25 nT/US ft with CENAB approval. Also, areas suspected of containing 37-mm projectiles (Powder Smoke Ridge and RA14 areas of Park) would be subject to the cut-off threshold of 12 nT/US ft. This strategy was used based on CENAB recommendation until the completion of the project.

3.1.7 Anomaly Dig Sheets

Following the identification of potential target anomalies from the geophysical data evaluation, the anomaly locations were digitized into a "dig sheet" based on the position of the target in UTM, Zone 18, North American Datum (NAD) coordinates. An electronic version of the Target Dig Sheet and Target History Database Form, which complies with the minimum requirements of Attachment C of USACE DID OE-005-05.01, was utilized to log excavated targets. The dig sheet data were uploaded into a PDA containing WESTON's UXOFast^{SM} software platform to facilitate target excavation and subsequent data transfer into a central GIS database. The Site Geophysicist assigned each anomaly a unique target identifier and entered the corresponding information for the target into the database.

At a minimum, the following information was included in the database for each targeted anomaly:

- Unique target ID including area (i.e., T3-1, [target area /target pick]).
- Easting and northing position.
- Channel ID (i.e., AS).
- Response amplitude of the peak response for the G-858 Analytic Signal.
- Dig priority based on correlation to target attributes.

The dig sheet also included QC target anomalies that were picked by the WESTON Site and/or Project Geophysicist. The dig sheets for each DGM grid (following DID OE-005-05.01, Attachment C) and M&D grid (four grids at the RA1 area) are provided in Appendix J.

3.1.8 Anomaly Reacquisition

A total of 6,067 DGM anomalies (4,952 from grids, 1,115 from transects) were selected for reacquisition and subsequent intrusive investigation at the Park and Game areas of TOAR. Reacquisition of DGM grid anomalies was performed by utilizing the USRADS navigation system. The USRADS was set up over the grid and each anomaly target was located and the precise location of the ferrous target was fine-tuned using the Schonstedt magnetic locator. A pin flag was then placed at the refined target location. This procedure was later modified per discussions with CENAB on 18 August 2004 and amended in the Work Plan and implemented going forward as follows:

1. WESTON will place the flag at the target coordinate. The UXO Technician will then scan the area with the Schonstedt magnetometer. The area scanned will be limited to a 2-ft radius around the flag. The flag will stay at the target coordinate; no fine-tune adjusting of the flag will be done.
2. If the Schonstedt detects an anomaly within the 2-ft radius, then the dig team will excavate the anomaly and record the distance from the flag to the dug item. The item will be QC'd to verify that the mass is consistent with the amplitude and size of the detected anomaly.
3. If the Schonstedt does not detect an anomaly, WESTON will first review the Geosoft Oasis montaj™ data to determine the nature of the mapped target, then follow one of two procedures:
    a. If the anomaly is a high amplitude anomaly and the DGM data contain no abnormalities, WESTON will attempt to reacquire this anomaly with the G-858 and then dig.
    b. If the target selection is suspect, WESTON will record the target as a "no contact" with an explanation on the dig sheet regarding the results of the re-evaluation, or reacquire the target with the G-858, depending on the results of the re-evaluation and results of adjacent digs, i.e., the target could have been a double pick on a single item.

Reacquisition of the DGM transect anomalies was performed using the Schonstedt magnetic locator and the Trimble Pro XRS GPS. The reacquisition teams located the coordinate position of the anomaly using the Trimble Pro XRS unit, placed a pin flag at that location, confirmed the presence of the ferrous anomaly with the Schonstedt unit, and then proceeded to excavate the anomaly. All pertinent excavation data were recorded in the PDA using the UXOFast^{SM} software platform for subsequent download.

3.1.9 Root-Cause Analysis

One of the goals throughout the site investigation was to achieve a high standard of quality DGM data. Based on QC checks and QA reviews by CENAB and/or CEHNC, corrections to data collection and/or processing procedures were made. Subsequent to an identified item requiring a corrective measure, a root-cause analysis was performed to document the issue, analysis and corrective action. Three such root-cause analyses were submitted to CENAB/CEHNC as memorandums and are summarized as follows:

- Data gaps in DGM data collected on 24 June 2004 (dated 7 July 2004).
- Evaluation of target selection threshold (dated 10 August 2004).
- Latency correction for DGM grids RA14G1-2, T1G3 and G7 and T4G4 (dated 14 September 2004).

Copies of the root-cause analysis memorandums are provided in Appendix K.

3.1.10 Intrusive Investigation

The intrusive investigation at the TOAR-FUDS was conducted from 19 April through 12 October 2004. A total of 6,067 DGM anomalies (4,952 from grids, 1,115 from transects) were intrusively investigated. A total of 56 items were identified during the M&D survey.

All 6,067 anomalies intrusively investigated were excavated by UXO-qualified personnel. During the intrusive investigation, each anomaly was treated as a suspect UXO item until it was determined otherwise. Occasionally, the dig teams could not identify any metallic objects at an anomaly location. These locations were designated as “false positives” and were shown as a “no contact” on the UXOFast^{SM} database dig sheet. Across the entire site, 392 “false positives” (6.4%) were identified from the DGM grid and transect anomalies selected for excavation. The presence of some “false positives” is inherent in DGM investigations with 15% considered the maximum acceptable occurrence level (USACE DID OE-005-05.01). Many reasons exist for the presence of “false positives” including residual iron in the soil, proximity of power lines, metallic surface debris moved after initial survey, rough terrain causing equipment jolts, end-of-line turn around, dipole picking, etc. None of the M&D anomalies, by definition, resulted in a "false positive." The results of the intrusive investigation are discussed in Section 4.

The WESTON Project Geophysicist compared the dig findings from each intrusively investigated anomaly (with the exception of M&D anomalies) with the maximum amplitude originally recorded by the G858 to ensure the item recovered was reasonable for the reading. If the excavated item was not consistent with the geophysical data, further investigation of the anomaly location was conducted. The disposition of each false positive was reconciled by the Project Geophysicist either through the DGM data or by a field check. A description as to the final disposition of the false positive was included in the UXOFast^{SM} database "comments" column.

After an anomaly was excavated, the dig team recorded through the UXOFast^{SM} PDA platform the anomaly type, a description of their findings, the anomaly depth and offset, and any actions taken. All this information was recorded electronically in real-time in the PDA. The UXOFast^{SM} PDA platform includes an electronic version of the Target Dig Sheet and Target History Database Form, which complies with the minimum requirements of Attachment C of USACE DID OE-005-05.01.

The available choices in UXOFast^{SM} for MEC-related anomaly types were defined as UXO, MPPEH, MD, and not applicable (NA). A UXOFast^{SM} designation of NA meant the anomaly item was "not MEC-related." If an excavated item was determined to be a "not MEC-related" (non-ordnance-related) anomaly type, the "item type code" drop-down menu choices in the UXOFast^{SM} PDA became:

- Non-ordnance-related (NON)
- No contact (NC)
- QC item (QC)
- Not applicable (NA).

In addition, the Project Geophysicist continually compared the dig results with the anticipated findings given the anomaly "priority rank" and amplitude. The anomaly types identified in the UXOFast^{SM} PDA (electronic "dig sheet") are briefly described in the following subsections.

3.1.10.1 Unexploded Ordnance (UXO)

Anomalies were identified as UXO (noted as anomaly type code UXO in UXOFast^{SM} database) if the recovered item was "a military munition that has been primed, fuzed, armed, or otherwise prepared for action, and has been fired, dropped, launched, projected or placed in such a manner as to constitute a hazard to operations, installation, personnel, or material and remain unexploded by either malfunction, design, or any other cause" (40 CFR 260.201).

3.1.10.2 Material Potentially Presenting an Explosive Hazard (MPPEH)

Anomalies were temporarily identified as MPPEH (noted as anomaly type code MPPEH in UXOFast^{SM} database) if the recovered item was a "material potentially containing explosives or munitions (including containers, packing material, munitions debris, and range related debris), or materials potentially contaminated with a high enough concentration of explosives such that the material presents an explosive hazard" (40 CFR 260.201). The disposition of MPPEH items found on-site was determined by a qualified UXO Technician. All MPPEH items were ultimately identified and recorded as either UXO, with a final disposition of "disposed by detonation" or "blown-in place," or as MD.

3.1.10.3 Munitions Debris (MD)

Anomalies were identified as MD (noted as anomaly type code MD in UXOFast^{SM} database) if the recovered item was a "remnant of munitions remaining after munitions use, demilitarization, or disposal" (40 CFR 260.201). All MD was considered MPPEH until inspected by a technically qualified person. Most items recovered through excavation were MD and included frag, empty projectiles, push plates, flash tubes, etc.

3.1.10.4 Not Applicable (NA)

Anomalies were identified as not applicable (noted as anomaly type code NA in UXOFast^{SM} database) if the recovered item was "not MEC-related". If an excavated item was determined to be a "not MEC-related" (non-ordnance-related) anomaly type, the "item type code" drop-down menu choices in the UXOFast^{SM} PDA became:

- Non-ordnance-related (NON)
- No contact (NC)
- QC item (QC)
- Not applicable (NA)

The not applicable or "not MEC-related" subcategories are described in the following subsections.

3.1.10.4.1 Non-Ordnance-Related (NON)

Anomalies were identified as non ordnance-related (item type code NON in UXOFast^{SM} database) if the recovered items were not related to any ammunition and/or ammunition-related components. These items typically included metal scrap such as nails, wire, cables and pipes. Non-ordnance-related items also include "geological interferences" such as iron-bearing rocks (rock) and boulder fields (BF), QA/QC seed items (QC) and no contacts (NC). No contacts are considered "false positives" and the disposition of each no contact was reconciled by the Project Geophysicist either through the DGM data or by a field check.

3.1.10.4.2 No Contact (NC)

An anomaly was identified as a non-ordnance related no contact or false positive (item type code NC in UXOFast^{SM} database), if no discernable metallic objects were identified at the anomaly excavation location and the magnetometer did not display an audible signal at the pin-flagged location or an approximate 3-foot radius surrounding the pin-flagged location. The disposition of each false positive was reconciled by the Project Geophysicist either through the DGM data or by a field check. A description as to the final disposition of the false positive was included in the UXOFast^{SM} database "comments" column.

3.1.10.4.3 QC Item (QC)

An anomaly was identified as a non-ordnance-related QC item (item type code QC in UXOFast^{SM} database) if the object identified at the anomaly excavation was a planted seed item. Such objects were typically a QA seed planted by a CENAB representative for QA purposes.

3.1.10.4.4 Not Applicable (NA)

An anomaly was identified as non-ordnance-related “not applicable” (item type code NA in UXOFast^{SM} database) if the excavated object could not be identified. However, this data item was never used.

3.1.10.5 Final Disposition of UXO and MD Recovered

UXO were disposed of by detonation or blown-in-place. Demolition activity reports are provided in Appendix L. MD items were inspected by technically qualified personnel to ensure they were inert. All scrap from disposed UXO, as well as MD and non-MEC, was submitted to the Environmental Office at TYAD at the end of the project. Documentation of the final disposition of munitions potentially presenting an explosive hazard, munitions debris, and wastes is provided in Appendix M.

3.2 SITE INVESTIGATION FOR MUNITIONS CONSTITUENTS

This section provides an overview of the environmental sampling for MC that was performed at the TOAR-FUDS. In this section and throughout the rest of this report, MC refers to chemical constituents that may be present as a result of the use of munitions at the TOAR-FUDS.

The intent of the environmental sampling program for this project was to assess the potential for MC contamination resulting from the use of munitions at the TOAR-FUDS, not to provide full site characterization. In this case, sampling includes surface soil, surface water, sediment, “background” surface soil, and test pit soil samples. Environmental samples were sent to and analyzed by Severn-Trent Laboratories in Pittsburgh, PA (STL-Pittsburgh) and Knoxville, TN (STL-Knoxville).

3.2.1 Munitions Constituents

Surface soil, surface water, and sediment samples were collected at the TOAR-FUDS to determine if surface soils have been impacted by MC. The approach for MC sampling, including the data quality objectives (DQOs), data collection rationale, sampling procedures, and QA goals, is presented in detail in Appendix E of the Work Plan, which was developed in concert with EPA, PADEP, and CENAB.

Surface soil samples were collected from biased-high locations (ordnance features such as detonation craters) within TAs, and "in front of" FPs. That is, samples were collected from within 50 to 100 feet of FPs, in the direction of TAs. The exact distance between each FP and each sample location varied based on the visual evidence collected. Three composite samples were collected from within each of the TAs and two composite samples were collected at each FP at a depth of 0 to 6 inches below ground surface (in. bgs). A total of forty four surface soil samples, including QC samples, were collected. Surface soil sample location coordinates are provided in Table 3-4. All sampling locations are shown in Figure 3-5.

Surface water and sediment samples were collected where surface water was ponding/pooling near TA sampling locations (not from flowing streams). A total of five surface water and sediment (SW/SD) samples adjacent to TA sampling locations were collected to determine if the SW/SD have been impacted. Sediment samples were collected at a depth of 0 to 6 in. bgs. Two SW/SD samples in the Park were located at Black Bear Swamp and the southeastern portion of Bender Swamp, and three samples in Game were located adjacent to Huckleberry Marsh, southwest of Still Swamp and Frame Cabin Run. All sample locations were surveyed for horizontal coordinates utilizing the Trimble Pro XRS GPS unit. Sediment and surface water sample location coordinates are provided in Table 3-4. All sampling locations are shown in Figure 3-5.

Anomaly avoidance was performed by a qualified UXO technician to ensure that no UXO hazards were present. Each sample location was "cleared" of ferrous material utilizing a Schonstedt magnetic locator prior to collecting the sample. The surface soil and SW/SD samples were analyzed for total metals using EPA Method 6010B/7000 Series and explosives residues using EPA 8330. All samples were submitted to STL-Pittsburgh and STL-Knoxville for

Table 3-4
Environmental Sampling Location Coordinates

Sample ID	Sample Type	X[1]	Y[1]	Z
spbg-001	Background	1511989.00121	14977937.07420	0 to 6 in bgs
spbg-002	Background	1539266.60175	14984155.14210	0 to 6 in bgs
spbg-003	Background	1536407.26689	14970843.46730	0 to 6 in bgs
spbg-04	Background	1529550.59901	14964602.96670	0 to 6 in bgs
glbg-005	Background	1529684.59908	14941719.91700	0 to 6 in bgs
glbg-006	Background	1509958.82117	14938055.47900	0 to 6 in bgs
glbg-007	Background	1496818.45176	14945033.94430	0 to 6 in bgs
glbg-007	Background	1496821.88288	14945038.47150	0 to 6 in bgs
glbg-008	Background	1498760.38867	14959332.23530	0 to 6 in bgs
T2SS1	Soil	1525128.55764	14971889.96410	0 to 6 in bgs
T2SS2	Soil	1524845.35143	14972505.58080	0 to 6 in bgs
T2SS3	Soil	1524449.66328	14973260.21490	0 to 6 in bgs
T3SS1	Soil	1524908.61330	14970190.17730	0 to 6 in bgs
T3SS2	Soil	1524261.76068	14970202.13020	0 to 6 in bgs
T3SS3	Soil	1524626.62437	14970215.51240	0 to 6 in bgs
T4SS1	Soil	1525353.10572	14967515.44090	0 to 6 in bgs
T3SW1/SD1	SW/SD	1525217.84467	14971895.84270	0 to 6 in bgs
T4SS2	Soil	1525344.41184	14968402.31770	0 to 6 in bgs
T4SS3	Soil	1525035.10795	14968792.26270	0 to 6 in bgs
T1SW1/SD1	SW/SD	1529002.84948	14971979.47480	0 to 6 in bgs
T11SW1/SD1	SW/SD	1504954.58250	14947364.69540	0 to 6 in bgs
T6SW1/SD1	SW/SD	1508626.79177	14960786.73730	0 to 6 in bgs
T1SS1	Soil	1531466.99004	14975357.20620	0 to 6 in bgs
T1SS2	Soil	1531394.77903	14974953.48560	0 to 6 in bgs
T1SS3	Soil	1530545.38786	14975127.26960	0 to 6 in bgs
FP2ASS1	Soil	1534860.22635	14969791.00760	0 to 6 in bgs
FP2ASS2	Soil	1534775.19131	14969609.23930	0 to 6 in bgs
FP2SS1	Soil	1533174.18080	14968359.78260	0 to 6 in bgs
FP2SS2	Soil	1533115.40625	14968167.71160	0 to 6 in bgs
FP3SS1	Soil	1515488.05808	14964712.07270	0 to 6 in bgs
FP3SS2	Soil	1515646.13482	14964833.94830	0 to 6 in bgs
FP5SS1	Soil	1521026.66888	14953244.26950	0 to 6 in bgs
FP5SS2	Soil	1521060.82758	14953091.78260	0 to 6 in bgs
FP4SS1	Soil	1519598.80986	14957881.20300	0 to 6 in bgs
FP4SS2	Soil	1519601.45685	14957638.27360	0 to 6 in bgs
T8SS1	Soil	1512903.86137	14955887.02790	0 to 6 in bgs
T8SS2	Soil	1513055.45391	14956632.01060	0 to 6 in bgs
T8SS3	Soil	1513057.51712	14957358.41810	0 to 6 in bgs
T10SS1	Soil	1506432.11496	14949726.77540	0 to 6 in bgs
T10SS2	Soil	1506589.59037	14950232.74300	0 to 6 in bgs
T10SS3	Soil	1506642.64592	14951039.54910	0 to 6 in bgs
T9SS1	Soil	1504744.85512	14952478.26140	0 to 6 in bgs
T9SS2	Soil	1505588.40598	14952444.17780	0 to 6 in bgs
T9SS3	Soil	1505806.55251	14952376.16880	0 to 6 in bgs
T7SS1	Soil	1503850.63879	14956068.34450	0 to 6 in bgs
T7SS2	Soil	1503603.19541	14956475.79250	0 to 6 in bgs
T7SS3	Soil	1503365.43581	14956614.30000	0 to 6 in bgs
T11SS1	Soil	1506024.49885	14946436.33310	0 to 6 in bgs
T11SS2	Soil	1506275.53478	14946100.47460	0 to 6 in bgs
T11SS3	Soil	1506546.92119	14945909.48760	0 to 6 in bgs
T6SS1	Soil	1507357.65873	14960211.86290	0 to 6 in bgs
T6SS2	Soil	1507656.94389	14959905.66330	0 to 6 in bgs
T6SS3	Soil	1508295.75182	14959713.78020	0 to 6 in bgs
RA11SW	SW/SD	1510606.29304	14955739.03490	0 to 6 in bgs
TP-1	Test Pit	1537155.09489	14973883.17290	NA
TP-2	Test Pit	1537159.00805	14973831.55330	NA
TP-3	Test Pit	1537189.06450	14973801.25960	NA
TP-4	Test Pit	1537206.63776	14973995.08770	7 ft bgs
TP-5	Test Pit	1537157.69052	14974004.28940	NA
TP-6	Test Pit	1537087.44596	14973984.02980	NA
TP-7	Test Pit	1537110.85981	14973986.08530	3 ft bgs
TP-8	Test Pit	1537248.99568	14973973.90800	NA

SW/SD = Surface Water and Sediment Sample
[1]X-Y Coordinate System = UTM Zone 18N, NAD83, US Survey Feet
NA = Not applicable. Samples were not collected at TP-1, 2, 3, 5, 6, and 8.

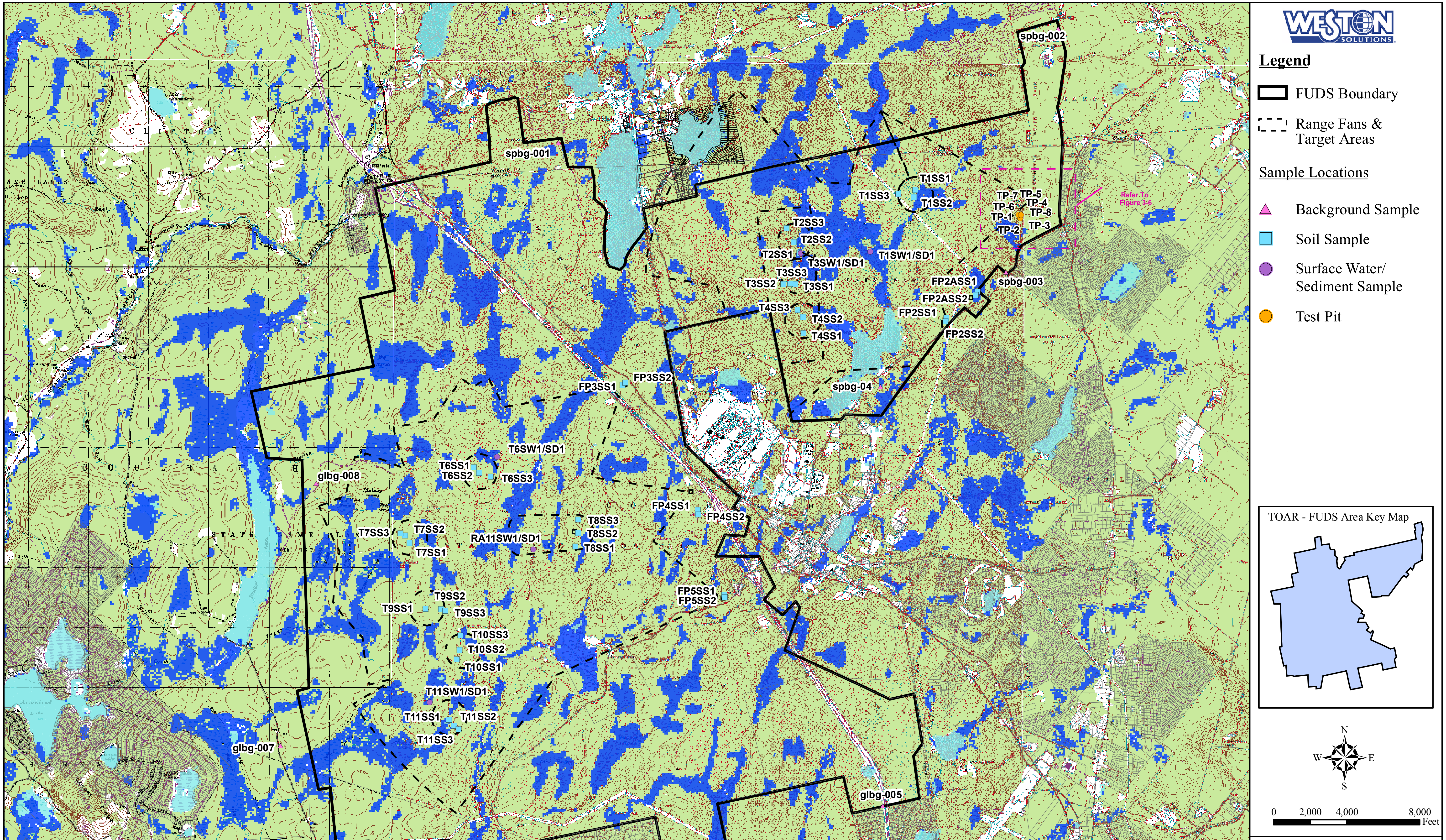


Figure 3-5
Environmental Sampling Locations for Munitions Constituents

T:/TobyhannaUXO/mxd/DRAFT_RIFS/DRAFT_MARCH/Env_Sampling_Loc_3-5.mxd 062705 analysis. Split samples were not collected by CENAB. The sample results are presented in Section 4.

3.2.2 Background Samples

Nine background surface soil samples (four each in the Park and Game, including QC) were collected on 11 October 2004 from eight locations in the Park and in the Game that were well outside areas of known or suspected MC contamination, and analyzed for metals only. Background surface soil samples were collected at a depth of 0 to 6 in. bgs. The sampling procedures outlined in the SAP, referenced in Appendix E of the Work Plan, were followed for collection of the composite background samples. Figure 3-5 shows the eight background metals sample locations.

3.2.3 Fill Area at Firing Point #1

During the field investigation at TOAR, an area of fill material containing municipal type trash was discovered adjacent to FP #1. In addition to this discovery, an empty 55-gallon drum was located on the surface adjacent to FP #1. According to personnel from the Tobyhanna Wildlife Conservation, Inc., this area may have formerly been used as a dump by the Park. The dump was believed to have been discontinued in the 1960s.

Although the area where the dump was located was not expected to contain MC contamination, test-pitting was performed to investigate for DMM associated with FP #1 and additional sampling was conducted for complete chemical characterization. The procedures and sampling protocol for "Test Pitting and Sampling at Fill Areas" is specified in Appendix M of the Work Plan.

Eight test pits were excavated on 13 October 2004 adjacent to FP #1 utilizing a backhoe to excavate the trenches through the soil and municipal type waste material. The test pits were approximately 10 ft in length by one bucket width (approximately 2-3 ft). An UXO qualified technician was present during test pit activities. Air monitoring was conducted using a photo-ionization detector (PID) to monitor for volatile organic vapors, combustible gases, particulate matter, and to ensure the Health and Safety of the sampling personnel. The samples were collected from areas within the fill area that presented the highest potential for contamination, based on the following:

- Visual observation of possible military and/or industrial/municipal disposed of material and/or staining due to possible contamination.
- Nasal observation of any strong and unusual odors emanating from excavated fill material.
- Elevated maximum levels of organic compounds as indicated by PID.

No DMM was found in the area. Two soil samples were collected for Target Compound List (TCL), volatile organic compounds (VOCs), TCL semivolatile organic compounds (SVOCs), pesticides/polychlorinated biphenyls (PCBs), metals, and explosives (per Work Plan, Appendix M) at test pits TP4 and TP7. The two grab samples were collected below the fill material, into native soil at depths of 7 ft and 3 ft bgs, respectively. Municipal trash was not found in the other six test pits. The test pit locations were surveyed from the approximate center of the test pit utilizing the Trimble Pro XRS GPS unit and subsequently uploaded into the project GIS database. The eight test pit locations adjacent to FP #1 and the locations of the two (2) test pit soil samples are shown in Figure 3-6.

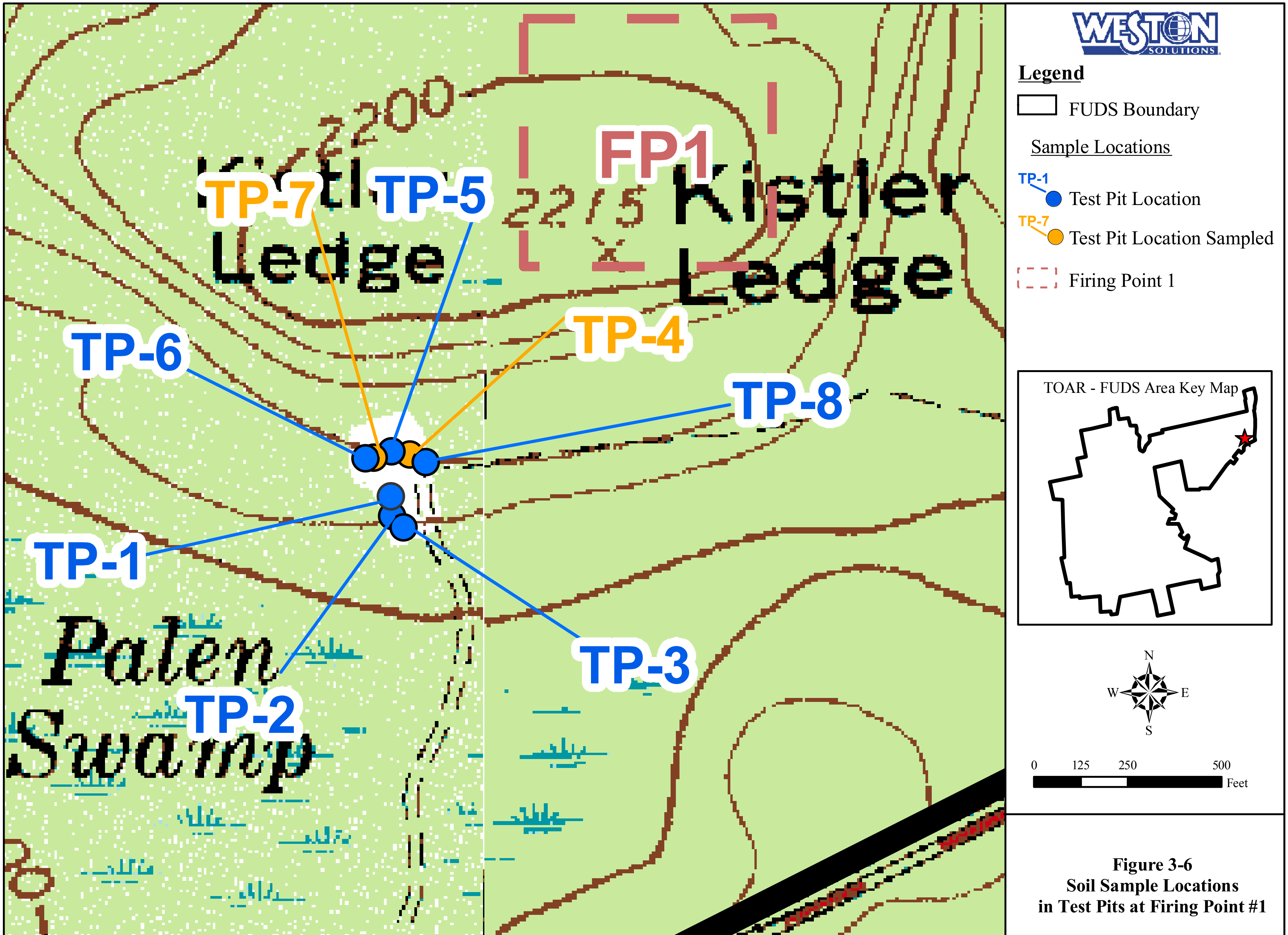


Figure 3-6
Soil Sample Locations
in Test Pits at Firing Point #1

T/TobyhannaUXO/mxds/DRAFT_RIFS/MARCH_DRAFT/TestPit_at_FP1_3-6.mxd 062705

4. SITE CHARACTERIZATION

This section provides an overview of the results of field investigations performed at the TOAR-FUDS for MEC and MC. Due to the significant number of tables and figures in this section, all referenced tables and figures appear at the end of Section 4.

4.1 SOURCE, NATURE, AND EXTENT OF MUNITIONS AND EXPLOSIVES OF CONCERN

The source, nature, and extent of MEC at the TOAR-FUDS was evaluated using data from previous investigations and data collected during this RI, which are described in the following subsections. No one data source is of itself sufficient to characterize the site, but when taken together they yield sufficient data for site characterization. The term MEC distinguishes specific categories of military munitions that may pose unique explosive safety risks, including the following:

- Unexploded ordnance (UXO) – Military munitions that fulfill the following criteria:
  - Have been primed, fuzed, armed, or otherwise prepared for action;
  - Have been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material; and
  - Remain unexploded either by malfunction, design, or any other cause (U.S.C. §2710 (e) (9)).
- Discarded military munitions (DMM) – Military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal. The term does not include UXO, military munitions that are being held for future use or planned disposal, or military munitions that have been properly disposed of consistent with applicable environmental laws and regulations. (10 U.S.C. §2710 (e) (2)).
- Munitions constituents such as TNT and RDX present in high enough concentrations to pose an explosive hazard (U.S. Army, 2005).

The nature and extent of MEC was investigated by sampling for UXO, DMM and Munitions Constituents (MC), which are any materials originating from UXO, discarded military munitions, or other military munitions, including explosive and non explosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions (10 U.S.C. §2710 (e)(4)).

No DMM have been recovered at the TOAR-FUDS, and no munitions constituents such as TNT and RDX have been found in high enough concentrations to pose an explosive hazard. All MEC recovered at the site to date have been classified as UXO.

The locations of all UXO recovered in Park and in Game are presented in Figures 4-1 and 4-2, respectively. The locations of MD items recovered in Park and in Game during the 2004 WESTON investigation are also shown in Figures 4-1 and 4-2, respectively. The data discussed in the following subsections are based on these maps and are used to develop the revised CSM, which is presented in Subsection 4.3 of this report.

4.1.1 Previous Investigations

4.1.1.1 Archives Search Report

As discussed in Subsection 2.7, in September 1995, USACE prepared an ASR for the TOAR-FUDS. The Rock Island District and Defense Ammunition Center and School prepared it for CEHNC (USACE, 1995). The ASR summarizes the site, historical ordnance presence, site eligibility for the FUDS program, and results of a visual site inspection, and provides an evaluation of ordnance and other site hazards.

Two main findings emerged from the ASR. First, the site is eligible for inclusion in DOD's Defense Environmental Restoration Program (DERP) FUDS program. Second, ordnance contamination is present and confirmed at numerous eligible sites on the TOAR-FUDS. The ASR assigned letter designators to various areas in an attempt to create "operable units (OUs)" for the report. Table 4-1 summarizes the results of the ASR findings.

4.1.1.2 1998 HFA TCRA in Park

CEHNC contracted with HFA in June 1997 to conduct a TCRA on several locations within the Tobyhanna State Park. All locations were within the boundaries of the Tobyhanna State Park and the areas included:

- Campgrounds (150 acres) to a depth of 2 ft.
- A total of 10 miles (approximately 18 acres) of hiking trails (the red, blue, and yellow trails) to a depth of 1 ft.
- Beach Area (4.5 acres) to a depth of 1 ft.
- Day use picnic area (20 acres) to a depth of 1 ft.
- Youth camping area (9 acres) to a depth of 2 ft.
- Area near the boat ramp (4 acres) to a depth of 1 ft.

HFA conducted the TCRA in 1998 and issued two clearance reports, one covering the trails and campgrounds, and the other covering all remaining areas.

The clearance reports contain a summary of the UXO and MD (referred to in the reports as “live and inert OE-related items,” respectively) removed from each area by HFA during the execution of the TCRA. A total of 278 “live OE” (UXO) and approximately 7,848 pounds of “OE-related scrap” (MD) were removed during the TCRA. UXO removed from each area is summarized in Table 4-2 and shown in Figure 4-1. Items found in the camping areas included 37-mm projectiles, which were probably fired from FP #7, located in what is now TYAD, and which probably overshot Powder Smoke Ridge. Other items found, including those along hiking trails, are consistent with the target areas, range safety fans, and historical information provided in the ASR. Approximately 83% of the “live OE” (UXO) were recovered from 0 to 6 in. bgs, 16% from 7 to 12 in. bgs, and 1% from 13 to 24 in. bgs. The HFA TCRA contributes 206 acres of data to the site characterization. The removals on the trail system in Park provide extensive transect data across the area.

Detailed information for the 1998 HFA TCRA can be found in the following report: *Partial Final Report, Time Critical Removal Action, Former Tobyhanna Artillery Range, Tobyhanna, Pennsylvania* (HFA, 1998).

4.1.1.3 1998 HFA Construction Support at TYAD

CEHNC contracted again with HFA to provide construction support for a radar site on Powder Smoke Ridge at TYAD. HFA conducted on-site removal activities in 1998. The footprint of the construction site (approximately 20 acres) and an area 100 feet around the footprint were cleared to a depth of 4 feet. The planned fence line and fence line footprint were cleared to a depth of 4 feet. All other areas within the construction site were cleared to a depth of 1 foot. All locations were within the boundaries of TYAD. A total of 228 UXO were removed during construction support activities. UXO removed are shown in Figure 4-1. All prior actions conducted at the TYAD add data that supports the CSM and the types of weapons and munitions employed at the TOAR-FUDS.

Detailed information for the 1998 HFA construction support project conducted on-post at TYAD can be found in the following report: *Draft Final Report, Construction Support Tobyhanna Army Depot, Tobyhanna, Pennsylvania* (HFA, 1999).

4.1.1.4 2004 WESTON Surface Clearance at TYAD

CENAB contracted with WESTON, Contract DACA31-00-D-0023, Task Order 0049, to conduct a surface removal of UXO prior to tree clearing activities related to the radar facility on Powder Smoke Ridge at TYAD. WESTON conducted the surface removal in 2004 along the 150-feet-wide tree clearing zone outside the radar facility perimeter fence line and in areas adjacent to the tree clearing zone for access. The area totaled approximately ten (10) acres. A total of seven (7) UXO items were removed during the surface clearance. UXO items removed are shown in Figure 4-1. All prior actions conducted at the TYAD add data that supports the CSM and the types of weapons and munitions employed at the TOAR-FUDS.

Detailed information for the 2004 WESTON construction support projects conducted on-post at TYAD can be found in the following report: *Site-Specific Final Report, MEC Surface Removal at Powder Smoke Ridge Radar Facility, Tobyhanna Army Depot* (WESTON, 2004c).

4.1.1.5 2004 WESTON Construction Support at TYAD

CENAB contracted with WESTON, Contract DACA31-00-D-0023, Task Order 0049, to provide construction support during geotechnical sampling at the proposed Training and Conference Center at TYAD. WESTON performed the construction support in 2004. No UXO items were identified on the ground surface or in the subsurface soils during construction support. All prior actions conducted at the TYAD add data that supports the CSM and the types of weapons and munitions employed at the TOAR-FUDS.

Detailed information for the 2004 WESTON construction support projects conducted on-post at TYAD can be found in the following report: *Final Report, MEC Removal Action at Proposed Training and Conference Center Site, Tobyhanna Army Depot,* (WESTON, 2005).

4.1.1.6 2004 WESTON TCRA in Game

CENAB contracted WESTON in September 2003 to conduct a TCRA on two roads in the southwest artillery range, 7-Mile Road and Trail No. 1. UXO clearance was conducted at four areas:

- 7-Mile Road.
- Trail Number 1.
- Parking areas along 7-Mile Road.
- Magazine area.

WESTON conducted the TCRA from March to June 2004. A total of 2,985 anomalies were identified and excavated during the TCRA effort. Within the 2,985 excavations, 1 UXO item, a 155-mm MK-1 shrapnel projectile with pusher plate, was identified and removed, and 33 MD items were identified and removed. The MD items included empty shrapnel rounds (75-mm and 155-mm), base plates, noses, and frag. A summary of UXO and MD items found during the 2004 TCRA is provided in Table 4-3. UXO and MD items found during the 2004 TCRA are included in Figure 4-2. The Weston TCRA for the roads and trails in the southwest artillery range contributes approximately 27 acres of data to the site characterization. Due to the nature of the removals, the roads essentially were major (20-30' wide) transects through the southwestern artillery range.

Detailed information for the 2004 WESTON construction support projects conducted on-post at TYAD can be found in the following report: *Final Report, Time-Critical Removal Action (TCRA), Removal of Munitions and Explosives of Concern (MEC) for Vehicle Access Roads, Pennsylvania State Game Lands #127, Tobyhanna, Pennsylvania,* (WESTON, 2004b).

4.1.2 2004 WESTON Remedial Investigation

PADEP contracted WESTON to conduct a site investigation to quantify the types, densities, and extent of MEC contamination at the TOAR-FUDS. This subsection provides an overview of the results of the field investigation performed from April to October 2004.

As discussed in Section 3, for the site investigation, Park and Game were divided into four AOIs, based on previous investigations and the reports and findings of UXO to date: FPs, TAs, RFs, and Other Areas (areas inside the FUDS boundary that are not part of FPs, TAs, or RFs). The AOIs are presented in the original CSM, presented as Figure 3-1, which is presented in Appendix I of the Work Plan. Also as discussed in Section 3, in August 2004, based on preliminary data collected during the RI, the CSM map was amended to reflect known site conditions. The amended maps for Park and Game are shown in Figures 4-1 and 4-2, respectively. The changes made to the original CSM included the combination of TAs #2, #3, and #4 into one TA, the enlargement of TA #8 to include items found to the west, and the presence of FP #2a.

The site was geophysically mapped and intrusively investigated using DGM and IAR methods, as presented in Section 3. Using DGM methods, 31.71 and 41.60 acres were mapped and investigated in Park and Game, respectively. Using IAR methods, 183.56 and 86.73 acres were investigated in Park and Game, respectively. A summary of the number of acres investigated is provided in Table 4-4. Also, as shown in Table 4-4, some DGM grids and transects in both Park and Game were mapped, but target anomalies were not dug. Areas were mapped but not dug for the following reasons:

- Safety – Some grids and transects were not dug due to safety concerns. During the field investigation, upon the detection of UXO, the minimum separation distance (MSD) for investigative work increased from 200 ft to 2,577 ft, based on the munition with the greatest fragmentation distance (MGFD), the 155-mm M107, as defined in subsection 3.9 of the EE/CA Work Plan, and the MSD had to be cleared in order to continue intrusive investigation work. However, the MSD could not be cleared in some areas of Park and Game: in Park, residential housing is located within 500 ft of UXO found inside the FUDS boundary; and in Game, hunters can be located anywhere on the site during hunting season. Due to the close proximity of UXO to residential housing, and the potentially close proximity of UXO to hunters, intrusive investigation in those areas was halted.

- Adequate characterization – Some grids and transects were not dug because the area of investigation had been adequately characterized based on UXO already recovered. In Park and Game, some grids and transects in impact areas were not intrusively investigated because a high density of UXO had already been recovered, and no additional investigation was necessary or cost-efficient.

A total of 6,422 anomalies (6,067 of which were identified by DGM methods) were selected for reacquisition and subsequent intrusive investigation. As summarized in Table 4-5, of the 6,422 anomalies investigated, 78 UXO were recovered at the site: 40 UXO items in Park, and 38 UXO items in Game. Also, 3,367 MD items were recovered, 2,584 non-MEC items were recovered, and 392 false positives were identified. A discussion of the anomalies investigated and items found in each AOI is provided in the following subsections.

4.1.2.1 Firing Points

An FP is the location where a weapon is prepared for and placed into use. For artillery, this involves the movement of munitions and propellant from a temporary storage structure. Proper propellant charges and the round are inserted into the weapon (e.g., howitzer) and it is fired. As a part of normal artillery firing, there are extra propellant pouches that are not used based on the distance to the target area. Possible MEC sources at a FP are lost or discarded items, and disposal of excess propellant by burning (common) or burial (less common). Mishandled, lost, or abandoned items are also possible in this area.

The locations of FPs at TOAR are shown in Figures 4-1 and 4-2. The northeast artillery range, located mostly within the Park, contained four FPs, #1, #2, #2a, and #3. Each FP generally contained four 75-mm/3-inch tubes (where the round was loaded and fired from) and one 155-mm tube. The FPs had stone parapets constructed adjacent to each tube to provide temporary storage and protection to ammunition and powder bags (propellant). Based on the aerial photographs compiled as part of the EPA EPIC study discussed in Subsection 2.7.1, when the artillery range was in operation, very few trees existed on-site. Now, the northeast artillery range is heavily wooded with artillery impact craters present throughout the range.

FP #1 is the northernmost firing point at the TOAR-FUDS. It fired at all four target areas (#1, #2, #3, and #4) in the northeast artillery range, and is located adjacent to Kistler Ledge[5]. FP #2 is located southwest of FP #1 and just north of Route 423, and fired at TAs #2, #3, and #4. FP #2a was not included in the original CSM, but its stone parapet was located early in the field investigation. FP #2a is just southwest of FP #2, and most likely fired at TAs #2, #3, and #4. FP #3 fired at TAs #6, #7, #9, and #10, which were located in Game.

The southwest artillery range, located mostly within Game, had three FPs, #4, #4a, and #5. These FPs were similar in construction to those in the northeast artillery range. FP #4 used TAs #8 through 11. FP #5 fired at TAs #6, #7, #9, and #10. When Interstate I-380 was constructed, the Army abandoned FP #4 and FP #4a was created[6]. FP #4a was sited in TA #8, which was abandoned for use as a target. FP #4a fired at TAs #6, #7, #9 and #10. Although FP #3 fired at TAs located in the southwest artillery range, because the FP itself was located in Park, FP #3 was investigated as part of Park.

4.1.2.1.1 Firing Points in Park

FPs in Park were investigated using the DGM transects and grids, IAR, M&D, and test trenching methods described in Section 3. Based on the anomaly ranking criteria and selection strategy discussed in Section 3, a total of 73 anomalies were intrusively investigated. Nine of the 73 anomalies investigated (12.3%) were considered “false positives” because no discernible metallic debris was found, which satisfies the DQO of 15% for false positives.

No DMM were recovered at the TOAR-FUDS, and no disposal pits were found. **Therefore, no MEC items were found that can be associated with former activities at FPs in Park.** Also, no MD items associated with former activities at FPs in Park were found. Non-MEC and false

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[5] Kistler Ledge was also historically known as Keesiler Ledge.

[6] This information is extracted from the ASR (para. 5 d (2)). However, the construction of Interstate I-380 could not be the cause of moving FP No. 4 because I-380 was not constructed until 1964, 25 years after the TOAR was returned to the Commonwealth of Pennsylvania. It is possible that the ASR meant to reference PA-611, which runs parallel to I-380 in this area.

positives found during intrusive investigation near FPs in Park were included in the totals for RFs, which are discussed below.

4.1.2.1.2 Firing Points in Game

FPs in Game were investigated using the DGM and IAR methods described in Section 3. Based on the anomaly ranking criteria and selection strategy discussed in Section 3, a total of 466 anomalies were intrusively investigated. Of the 466 anomalies investigated, 12 (2.6%) were considered "false positives" because no discernible metallic debris was found, which satisfies the DQO of 15% for false positives.

No DMM were recovered at the TOAR-FUDS, and no disposal pits were found. **Therefore, no MEC items were found that can be associated with former activities at FPs in Park.** Also, no MD items associated with former activities at FPs in Game were found. Non-MEC items and false positives found during intrusive investigation near FPs in Game were included in the totals for RFs, which are discussed below.

4.1.2.2 Target Areas

A target area is a fixed area where weapons were targeted. The ordnance item either functioned correctly (complete detonation) on target or the item malfunctioned, causing incomplete detonation or a dud fire in which the ordnance item failed to function as designed. Detonation of any order results in explosive residuals associated with the explosion. Complete detonations (functioned as designed) result in less explosive residuals than an incomplete detonation. For example, if they functioned as designed, HE rounds left behind only small fragments, while shrapnel rounds left behind the entire outer casing and, in some cases, the fuze. In addition, as part of range maintenance activities, the fired munitions and scrap material (old targets or expended munitions) may have been collected and buried in a disposal pit in the vicinity of the target. Discarded non-used MEC items are unlikely within this area. The locations of TAs at TOAR are shown in Figures 4-1 and 4-2, and described in Subsection 4.1.1.

4.1.2.2.1 Target Areas in Park

39.36 acres of TAs in Park were investigated. 10.75 acres of TAs in Park were geophysically mapped and investigated using DGM methods, and the remaining 28.61 acres were investigated using IAR methods. Based on the anomaly ranking criteria and selection strategy discussed in Section 3, a total of 1,983 anomalies were intrusively investigated. Of the 1,983 anomalies investigated 137 (6.9%) were considered “false positives” because no discernible metallic debris was found, which satisfies the DQO of 15% for false positives.

Thirty-four (34) UXO were found in TAs in Park. The locations of UXO found are presented in Figure 4-1. Intrusive investigation results for UXO found in TAs are presented in Table 4-6. Most UXO found in TAs in the Park were 75-mm and 155-mm projectiles, including both shrapnel and HE rounds. Several 37-mm projectiles were also found. The distribution and number of UXO found is summarized in Table 4-7. UXO were found at depths ranging from 0 in. bgs to 14 in. bgs, with most items found between 0 and 6 in. bgs, as summarized in Table 4-8.

Other recovered items from the intrusive investigation consisted of 1,706 items identified as MD and 106 items identified as non-MEC material. MD recovered included frag, base plates, empty projectiles, flash tubes, expended fuzes, and noses. At the TOAR-FUDS, empty projectiles were the principal MD that might have been indicative of a UXO presence. Therefore, empty projectiles are shown in orange (as opposed to yellow for other MD) in Figure 4-1. Non-MEC recovered included metal scrap, iron scrap, rock, monuments, wire, chains, nails, drums, pipe, horseshoes, rebar, shovels, barbed wire, etc. The intrusive investigation results for all items are presented in Appendix J.

4.1.2.2.2 Target Areas in Game

26.06 acres of TAs in Game were investigated. 14.58 acres of TAs in Game were geophysically mapped and investigated using DGM methods, and the remaining 11.48 acres were investigated using IAR methods. Based on the anomaly ranking criteria and selection strategy discussed in Section 3, a total of 1,300 anomalies were intrusively investigated. Of the 1,300 anomalies investigated 110 (8.5%) were considered “false positives” because no discernible metallic debris was found, which satisfies the DQO of 15% for false positives.

Twenty-two (22) UXO were found in TAs in Game. The locations of UXO found are presented in Figure 4-2. Intrusive investigation results for UXO found in TAs are presented in Table 4-6. UXO found in TAs in Game included 75-mm and 155-mm projectiles, including both shrapnel and HE rounds, and one 81-mm mortar round found in TA #6. The distribution and number of UXO found is summarized in Table 4-7. UXO were found at depths ranging from 0 in. bgs to 12 in. bgs, with most items found between 0 and 6 in. bgs, as summarized in Table 4-8.

Other recovered items from the intrusive investigation consisted of 954 items identified as MD and 214 items identified as non-MEC material. MD recovered included frag, base plates, empty projectiles, flash tubes, expended fuzes, and noses. At the TOAR-FUDS, empty projectiles were the principal MD that might have been indicative of a UXO presence. Therefore, empty projectiles are shown in orange (as opposed to yellow for other MD) in Figure 4-2. Non-MEC recovered included metal scrap, iron scrap, rock, monuments, wire, chains, nails, drums, pipe, horseshoes, rebar, shovels, barbed wire, etc. The locations of MD found in TAs in Game are presented in Figure 4-2. The intrusive investigation results for all items found are presented in Appendix J.

4.1.2.3 Range Safety Fans

A range safety fan (RF) is created during firing operations to provide a safety zone for ordnance that does not land on target. This area is a buffer area extending out from the FP to beyond the TA. RFs may include items that were short of the TA and items that overshot the TA. The RF may also include shots to the left and right (wide) of the TA. The ordnance items either functioned correctly (complete detonation) on target or the items malfunctioned, causing incomplete detonation or a dud fire in which the ordnance item failed to function as designed, thereby creating UXO. If they functioned as designed, HE rounds left behind only small fragments, while shrapnel rounds left behind the entire outer casing and, in some cases, the fuze. MC are also associated with this area. Disposal pits may also be present within the RF. The disposal pits would include munitions that were fired and collected within the RF. The locations of RFs at TOAR are shown in Figures 4-1 and 4-2.

4.1.2.3.1 Range Safety Fans in the Park

112.52 acres of RFs in Park were investigated. 10.18 acres of RFs in Park were geophysically mapped and investigated using DGM methods, and the remaining 102.34 acres were investigated using IAR methods. Based on the anomaly ranking criteria and selection strategy discussed in Section 3, a total of 993 anomalies were intrusively investigated. Of the 993 anomalies investigated, 76 (7.7%) were considered “false positives” because no discernible metallic debris was found, which satisfies the DQO of 15% for false positives.

Six (6) UXO were found in RFs in Park. The locations of UXO found are presented in Figure 4-1. Intrusive investigation results for UXO found in RFs are presented in Table 4-9. UXO found in RFs in Park included one 37-mm, two 75-mm, and three 155-mm projectiles, including shrapnel and HE rounds, and frag. The distribution and number of UXO found is summarized in Table 4-7. UXO were found at depths ranging from 0 in. bgs to 4 in. bgs, as summarized in Table 4-8.

Other recovered items from the intrusive investigation consisted of 177 items identified as MD and 798 items identified as non-MEC material. MD recovered included frag, base plates, empty projectiles, flash tubes, expended fuzes, and noses. At the TOAR-FUDS, empty projectiles were the principal MD that might have been indicative of a UXO presence. Therefore, empty projectiles are shown in orange (as opposed to yellow for other MD) in Figure 4-1. Non-MEC recovered included metal scrap, iron scrap, rock, monuments, wire, chains, nails, drums, pipe, horseshoes, rebar, shovels, barbed wire, etc. The locations of MD found in RFs in Park are presented in Figure 4-1. The intrusive investigation results for all items are presented in Appendix J.

4.1.2.3.2 Range Safety Fans in the Game

47.81 acres of RFs in Game were investigated. 10.90 acres of RFs in Game were geophysically mapped and investigated using DGM methods, and the remaining 36.91 acres were investigated using IAR methods. Based on the anomaly ranking criteria and selection strategy discussed in Section 3, a total of 444 anomalies were intrusively investigated. Of the 444 anomalies, 13 (2.9%) investigated were considered “false positives” because no discernible metallic debris was found, which satisfies the DQO of 15% for false positives.

Sixteen (16) UXO were found in RFs in Game. The locations of UXO found are presented in Figure 4-2. Intrusive investigation results for UXO found in RFs are presented in Table 4-9. UXO found in RFs in Game included 75-mm and 155-mm projectiles, including both shrapnel and HE rounds, and one 155-mm fuze. The distribution and number of UXO found is summarized in Table 4-7. UXO were found at depths ranging from 0 in. bgs to 24 in. bgs, with most items found between 0 and 6 in. bgs, as summarized in Table 4-8.

Other recovered items from the intrusive investigation consisted of 515 items identified as MD and 357 items identified as non-MEC material. MD recovered included frag, base plates, empty projectiles, flash tubes, expended fuzes, and noses. At the TOAR-FUDS, empty projectiles were the principal MD that might have been indicative of a UXO presence. Therefore, empty projectiles are shown in orange (as opposed to yellow for other MD) in Figure 4-2. Non-MEC recovered included metal scrap, iron scrap, rock, monuments, wire, chains, nails, drums, pipe, horseshoes, rebar, shovels, barbed wire, etc. The locations of MD found in RFs in Game are presented in Figure 4-2. The intrusive investigation results for all items are presented in Appendix J.

4.1.2.4 Other Areas

"Other Areas" at the site are defined as those areas inside the FUDS boundary that are not part of FPs, TAs, or RFs. Other Areas at TOAR are shown outside FPs, TAs, and RFs in Figures 4-1 and 4-2.

4.1.2.4.1 Other Areas in the Park

63.39 acres of Other Areas in Park were investigated. 10.78 acres of Other Areas in Park were geophysically mapped and investigated using the DGM methods, and the remaining 52.61 acres were investigated using the IAR methods. Based on the anomaly ranking criteria and selection strategy discussed in Section 3, a total of 481 anomalies were intrusively investigated. Of the 481 anomalies investigated, 27 (5.6%) were considered "false positives" because no discernible metallic debris was found, which satisfies the DQO of 15% for false positives.

No UXO were recovered in Other Areas in Park. The recovered items from the intrusive investigation consisted of 454 items identified as non-MEC material. Non-MEC recovered included metal scrap, iron scrap, rock, monuments, wire, chains, nails, drums, pipe, horseshoes, rebar, shovels, barbed wire, etc. The intrusive investigation results for all items are presented in Appendix J.

4.1.2.4.2 Other Areas in the Game

54.46 acres of Other Areas in Game were investigated. 16.12 acres of Other Areas in Game were geophysically mapped and investigated using the DGM methods, and 38.34 acres were investigated using the IAR methods. Based on the anomaly ranking criteria and selection strategy discussed in Section 3, a total of 682 anomalies were intrusively investigated. Of the 682 anomalies investigated, 11 (1.6%) were considered “false positives” because no discernible metallic debris was found, which satisfies the DQO of 15% for false positives.

No UXO were recovered in Other Areas in Game. The recovered items from the intrusive investigation consisted of 16 items identified as MD and 655 items identified as non-MEC material. MD recovered included one empty 75-mm projectile, one nose, one push plate, and frag. At the TOAR-FUDS, empty projectiles were the principal MD that might have been indicative of a UXO presence. Therefore, the empty projectile is shown in orange (as opposed to yellow for other MD) in Figure 4-2. Non-MEC recovered included metal scrap, iron scrap, rock, monuments, wire, chains, nails, drums, pipe, horseshoes, rebar, shovels, barbed wire, etc. The location of the MD found in Other Areas in Game is presented in Figure 4-2. The intrusive investigation results for all items are presented in Appendix J.

4.1.2.5 UXO Density

The density of UXO was calculated for AOIs in Park and Game using the acreage investigated (including both DGM and IAR data) and the number of UXO found. The UXO density at FPs was not calculated due to their relatively small area, and the fact that no MEC associated with FPs were found. As expected, densities of UXO were highest in TAs in Park and Game, while RFs in Park and Game contained the second highest density of UXO. No items were found in Other Areas. UXO densities are summarized in Table 4-10.

4.1.3 Conclusions for Munitions and Explosives of Concern

Using the data from all sources the site can be characterized with a high degree of certainty for MEC contamination. In total, approximately 578 acres of the site have been physically investigated or subjected to some form of removal action. In Park, total acres investigated were as follows:

- 1998 HFA TCRA – 187.5 acres were investigated in selected areas.
- 1998 HFA TCRA – 18 acres along were investigated hiking trails.
- 2004 WESTON RI – 31.71 acres were investigated using DGM.
- 2004 WESTON RI – 183.56 acres were investigated using IAR.
- Site visits – numerous acres have been visually inspected during site visits.

In Game, total acres investigated were as follows:

- 2004 WESTON TCRA – 27 acres were investigated along roadways and trails.
- 2004 WESTON RI – 41.60 acres were investigated using DGM.
- 2004 WESTON RI – 86.73 acres were investigated using IAR.
- Site visits – numerous acres have been visually inspected during site visits.

During the 2004 WESTON RI, a total of 6,422 anomalies were selected for reacquisition and subsequent intrusive investigation. As summarized in Table 4-2, of those 6,422 anomalies investigated, 78 UXO were recovered at the site: 40 UXO in Park, and 38 UXO in Game. Also, 3,367 MD were recovered, 2,584 non-MEC were recovered, and 392 false positives were identified. MD recovered included frag, base plates, empty projectiles, flash tubes, expended fuzes, and noses. At the TOAR-FUDS, empty projectiles were the principal MD that might have been indicative of a UXO presence. Therefore, empty projectiles are shown in orange (as opposed to yellow for other MD) in Figures 4-1 and 4-2. No disposal pits were found and no DMM was recovered at the site.

In addition to those items recovered during the 2004 WESTON RI, UXO recovered during previous activities include the following:

- 278 UXO recovered in Park (at the campground and along trails) during 1998 HFA TCRA.
- 228 UXO recovered on-post at TYAD (at the radar facility) during 1998 HFA construction support activities.
- 7 UXO recovered on-post at TYAD (adjacent to the radar facility) during 2004 WESTON construction support activities.
- 1 UXO recovered in Game (near 7-Mile Road and Jeep Trail) during 2004 WESTON TCRA.
- 3 UXO recovered in Park (near trails) during 2004 WESTON site visit.
- 2 UXO recovered in Park (near the northern FUDS boundary) during 2004 CENAB site visit.

Based on the results of the site characterization, the largest artillery used at the TOAR-FUDS was 155-mm. As shown in Figures 4-1 and 4-2, all UXO recovered during all investigations were recovered in TAs and RFs where UXO contamination was expected based on historical artillery range use. No MEC could be associated with former activities at FPs, and no UXO were recovered in Other Areas, which was expected because Other Areas were outside the area of expected or anticipated contamination. Therefore, the results of the field investigation generally support the ASR and the original CSM. However, revisions to the CSM are appropriate to account for high densities of UXO and MD in some areas. Those revisions are discussed in subsection 4.3.

4.2 PRESENCE/ABSENCE OF MUNITIONS CONSTITUENTS CONTAMINATION

Due to the chemical composition of the military munitions used at the TOAR-FUDS, there is a possibility that there may be residual contamination resulting from UXO present at the site. This contamination could result from the use of munitions where MC were released to the environment incidental to use, such as the projection of lead balls into the environment from the shrapnel rounds, degradation of munitions components from partially or non-functioned employed munitions that are exposed to the environment, degradation of DMM, or residues from destruction operations such as propellant burn pits in/around the FPs.

Explosives and explosive components used at the TOAR-FUDS were of the World War (WW) I to early WW II vintage. In addition to the metal housing (primarily lead) of the munitions themselves, the primary compounds used were TNT and black powder as a main or expulsion charge. Other constituents that possibly could be encountered (although not very likely since they were contained within the fuzes) were lead azide, lead styphnate, tetryl, and mercury fulminate. If the fuzes functioned as designed, there would be little to no trace of these materials since they would be consumed during the explosive initiation process. Samples were not analyzed for more advanced compounds, such as additives and plasticizers, as they would not have been used prior to WW II.

As described in subsection 3.2, environmental samples were collected and analyzed for MC to assess the presence/absence of MC contamination resulting from the use of munitions at the TOAR-FUDS and to evaluate the potential risk associated with MC contamination to human health and the environment, not to provide full site characterization. Therefore, samples were collected at biased-high locations (ordnance features such as detonation craters) within TAs and "in front of" FPs. That is, samples were collected from within 50 to 100 feet of FPs, in the direction of TAs. The exact distance between each FP and each sample location varied based on the visual evidence collected. Samples were analyzed for metals and explosives formerly used at the site. All sample locations at the TOAR-FUDS are shown in Figure 3-5. MC sample locations within TAs are presented at a smaller scale, along with UXO recovered, in Figures 4-3 through 4-13. MC sample locations adjacent to FPs are not presented at a smaller scale because no MEC was recovered that could be associated with FPs.

This subsection provides a summary of the analytical results for MC samples collected at the TOAR-FUDS, and a comparison of these analytical results with background samples collected at the TOAR-FUDS and/or local and regional background concentrations. In subsection 7.2, the analytical results presented in this section are analyzed statistically for natural variability and compared to applicable regulatory criteria and background or reference values to evaluate potential risk to human health and the environment. Complete analytical data packages are presented in Appendix N of this report.

4.2.1 Surface Soil

A total of 44 surface soil samples (referred to in this subsection as MC soil samples) were collected at FPs and in TAs from within ordnance features, such as detonation craters, and analyzed for metals and explosives. Also, nine background surface soil samples (referred to in this subsection as background soil samples) were collected from various locations in Park and in Game that were well outside areas of known or suspected MC contamination, and analyzed for metals only.

4.2.1.1 Metals in Surface Soils

Past practices associated with the TOAR-FUDS may have led to elevated results for certain metal constituents. Background soil sample results are shown in Table 4-11. MC soil sample results are shown in Table 4-12. MC soil sample results are compared to background soil sample results and regional background concentrations in Table 4-13. Based on available literature, regional background concentrations of metals in surface soil indicate that mean levels for some metals for this region may be higher than regulatory benchmarks.

The TOAR-FUDS dealt with a wide variety of ordnance, as described in the ASR (USACE, 1995). Metals are contained in various parts of ordnance, including the bodies of munitions, primary explosives, propellants, tracer compounds, igniter compounds, smoke compounds, etc. According to the Pennsylvania Game Commission, certain areas in Game have been sprayed with herbicides in preparation for timber sales. There is no record of the use of pesticides at the site.

This discussion of analytical results for metals will focus on the following metals: antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. Possible source materials, such as metallic debris, where observed, will be mentioned in this discussion. Metals that are detected above regional and background concentrations will also be discussed. All metal results are screened against applicable criteria in subsection 7.2.

Antimony concentrations in background soil samples ranged from 0.41 milligrams per kilogram (mg/kg) to 0.99 mg/kg. Antimony concentrations in MC soil samples ranged from 0.45 mg/kg to 10 mg/kg. Approximately 40% of the MC soil samples exceeded site-specific maximum background concentrations and maximum background concentrations in Pennsylvania. Lead antimony was used in small arms ammunition at the site.

Arsenic concentrations in background soil samples ranged from 2.5 mg/kg to 8.8 mg/kg. Arsenic concentrations in MC soil samples ranged from 2.0 mg/kg to 22.7 mg/kg. Seven of the MC soil samples exceeded site-specific maximum background concentrations. The mean and maximum background concentrations for arsenic in Pennsylvania soils both exceed the site-specific background results. Five MC soil samples exceeded the mean for Pennsylvania, and no MC soil samples exceeded the maximum for Pennsylvania.

Beryllium results were below method detection limits (MDLs) in background soil samples. Beryllium concentrations in MC soil samples ranged from 0.055 mg/kg to 1.7 mg/kg. No MC soil samples exceeded maximum background concentrations for Pennsylvania.

Cadmium concentrations in background soil samples ranged from 0.41 mg/kg to 1.1 mg/kg. Cadmium concentrations in MC soil samples ranged from 0.15 mg/kg to 1.5 mg/kg. One of the MC soil samples exceeded site-specific maximum background concentrations, and no MC soil samples exceeded the mean or maximum background concentrations for Monroe County.

Chromium concentrations in background soil samples ranged from 3.1 mg/kg to 9 mg/kg. Chromium concentrations in MC soil samples ranged from 2 mg/kg to 11.6 mg/kg. Six of the MC soil samples exceeded site-specific maximum background concentrations, no MC soil samples exceeded the mean or maximum background concentrations for Monroe County, and no MC soil samples exceeded the mean or maximum background concentrations for Pennsylvania.

Copper concentrations in background soil samples ranged from 4.9 mg/kg to 12.6 mg/kg. Copper concentrations in MC soil samples ranged from 3.7 mg/kg to 167 mg/kg. One-third of the MC soil samples exceeded site-specific maximum background concentrations, one MC soil sample exceeded the mean or maximum background concentrations for Monroe County, and one MC soil sample exceeded the mean or maximum background concentrations for Pennsylvania.

This sample was collected at FP #2a. Neither MEC nor MD were found in the vicinity of FP #2a. The high concentrations of lead found at this site are often associated with higher concentrations of copper.

Lead concentrations in background soil samples ranged from 15.2 mg/kg to 115 mg/kg. Lead concentrations in MC soil samples ranged from 23.4 mg/kg to 611 mg/kg. Approximately one-fourth of the MC soil samples exceeded site-specific maximum background concentrations, approximately 40% of the MC soil samples exceeded maximum background concentrations in Monroe County, and all but five MC soil samples exceeded maximum background concentrations in Pennsylvania. UXO and MD were found in almost all areas where MC soil samples were collected and lead concentrations were high. Lead balls were used as filler/weight in ammunition used at the site, including 37-mm, 75-mm, 155-mm, and 3-inch A-A shrapnel shells, and lead azide was a primary explosive used for initiation.

Mercury concentrations in background soil samples ranged from 0.074 mg/kg to 0.21 mg/kg. Mercury concentrations in MC soil samples ranged from 0.051 mg/kg to 0.47 mg/kg. One MC soil sample exceeded site-specific maximum background concentrations, and one MC soil sample exceeded the maximum background concentrations in Pennsylvania. This sample (F2-SS-4257-001) was collected at FP #2. Although several metals were detected at elevated concentrations in F2-SS-4257-001, the second MC soil sample collected at FP #2 contained much lower concentrations of most metals sampled, and no MEC or MD at FP #2 were found.

Nickel concentrations in background soil samples ranged from 1.3 mg/kg to 6.2 mg/kg. Nickel concentrations in MC soil samples ranged from 1.0 mg/kg to 13.5 mg/kg. Three MC soil samples exceeded site-specific maximum background concentrations, but none of the MC soil samples exceeded the mean or maximum background concentrations for Monroe County or Pennsylvania.

Selenium concentrations in background soil samples ranged from 0.57 mg/kg to 1.9 mg/kg. Selenium concentrations in MC soil samples ranged from 0.38 mg/kg to 4.7 mg/kg. Two MC soil samples exceeded site-specific maximum background concentrations, and approximately 40% of the MC soil samples exceeded the maximum background concentrations for Pennsylvania. One of the two MC soil samples exceeding site-specific maximum background concentrations (F2-SS-4257-001) was collected at FP #2. Although several metals were detected at elevated concentrations in that sample, the second MC soil sample collected at FP #2 contained much lower concentrations of most metals, and no MEC or MD associated with FP #2 were found.

Silver concentrations in background soil samples ranged from 0.3 mg/kg to 1.1 mg/kg. Silver concentrations in MC soil samples ranged from 0.039 mg/kg to 1.2 mg/kg. One MC soil sample (T6-SS-4259-001) exceeded site-specific maximum background concentrations.

Thallium results were below MDLs in background soil samples. Thallium was detected in nine MC soil samples, ranging from 0.59 mg/kg to 1.4 mg/kg. None of the MC soil samples exceeded site-specific maximum background concentrations or maximum background concentrations for Pennsylvania.

Zinc concentrations in background soil samples ranged from 14.1 mg/kg to 61.8 mg/kg. Zinc concentrations in MC soil samples ranged from 10.9 mg/kg to 154 mg/kg. Five MC soil samples exceeded site-specific mean or maximum background concentrations, and none of the MC soil samples exceeded the maximum background concentrations for Monroe County or Pennsylvania.

4.2.1.2 Explosives in Surface Soils

HMX was the only explosive compound detected above MDLs in any of the MC soil samples. HMX was detected in one MC soil sample collected from FP #2a at a concentration of 0.069 mg/kg, which is above the minimum detection limit (0.048 mg/kg) but below the reporting limit (0.50 mg/kg). No MEC or MD were found at or near FP #2a during the site investigation. Explosives results for all surface soil samples are presented in Table 4-14.

4.2.1.3 Conclusions for Surface Soils

Surface soils within ordnance features at the site appear to have been impacted by lead, based on the following factors:

- Lead was a common component in most ammunition used at the site.

- Lead results exceeded site-specific maximum background concentrations and regional and county-specific maximum background concentrations.
- Surface soil samples were collected from biased-high locations, as shown in Figures 4-3 through 4-13.

Other metals that appear to have impacted surface soils within ordnance features at the site include antimony, arsenic, and copper. The risk posed by metals in surface soils to human health and the environment (i.e., ecological impacts) is further evaluated in subsection 7.2 where analytical results are compared to applicable regulatory criteria and background or reference values. Explosives do not appear to have impacted surface soils within ordnance features at the site.

4.2.2 Sediment

Six sediment samples were collected from locations where surface water was ponding/pooling near target sampling areas (not from flowing streams) and analyzed for metals and explosives.

4.2.2.1 Metals in Sediment

Sediment sample results for metals are shown in Table 4-15. Sediment sample results for metals are compared to background concentrations, collected as part of the TYAD Ecological Risk Assessment (ERA) in 1997, in Table 4-16. As mentioned in the discussion of metals in surface soil samples in Subsection 4.2.1, elevated levels for certain metal constituents in sediments and soils may be associated with past activities at the site. Also, regional background soil concentrations for metals may be at higher levels. This discussion of analytical results for metals will focus on the following metals based on historical practices at the site: antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. All metal results are screened against applicable criteria in subsection 7.2.

Antimony was detected in one sediment sample (RA11-SD-4259-001) at a concentration of 0.63 mg/kg. Antimony was not detected in background sediment samples collected for the TYAD ERA in 1997, but that concentration is lower than the reporting limit for antimony (7.14 mg/kg) defined in the 1997 report.

Arsenic was detected in all six sediment samples, with concentrations ranging from 2.2 mg/kg to 6.2 mg/kg. Only the highest concentration exceeded the mean background concentration at TYAD, but none of the samples exceeded the maximum background concentration.

Beryllium was detected in three of the six sediment samples, with concentrations ranging from 0.14 mg/kg to 0.97 mg/kg. Beryllium was not detected in background sediment samples collected for the TYAD ERA in 1997, but the higher result in RA11-SD-4259-001 was the only result that exceeded the reporting limit for beryllium (0.5 mg/kg) defined in the 1997 report.

Cadmium was detected in all six sediment samples, with concentrations ranging from 0.56 mg/kg to 1.7 mg/kg. Four samples exceeded the mean background concentration at TYAD, but none of the samples exceeded the maximum background concentration from the TYAD ERA in 1997.

Chromium was detected in all six sediment samples, with concentrations ranging from 3.6 mg/kg to 12.5 mg/kg. Chromium was not detected in background sediment samples collected for the TYAD ERA in 1997.

Copper was detected in all six sediment samples, with concentrations ranging from 1.6 mg/kg to 31.5 mg/kg. Two samples exceeded the mean background concentration at TYAD, and one sample (T3-SD-4252-001) exceeded the maximum background concentration.

Lead was detected in all six sediment samples, with concentrations ranging from 8.6 mg/kg to 113 mg/kg. One sample exceeded the mean background concentration at TYAD, but none of the samples exceeded the maximum background concentration.

Mercury was detected in five of the six sediment samples, with concentrations ranging from 0.04 mg/kg to 0.26 mg/kg. Mercury was not detected in background sediment samples collected for the TYAD ERA in 1997.

Nickel was detected in all six sediment samples, with concentrations ranging from 4.8 mg/kg to 11.5 mg/kg. Five samples exceeded the mean background concentration at TYAD, but none of the samples exceeded the maximum background concentration.

Selenium was detected in all six sediment samples, with concentrations ranging from 0.37 mg/kg to 1.7 mg/kg. All six samples exceeded the mean background concentration at TYAD, but none of the samples exceeded the maximum background concentration.

Silver was detected in only one sediment sample, at a concentration of 0.52 mg/kg. Silver was not detected in background sediment samples collected for the TYAD ERA in 1997, and the above concentration does not exceed the reporting limit for silver (0.589 mg/kg) defined in the 1997 report.

Thallium results were below MDLs in all sediment samples.

Zinc was detected in all six sediment samples, with concentrations ranging from 30.2 mg/kg to 116 mg/kg. No samples exceeded the mean background concentration at TYAD.

4.2.2.2 Explosives in Sediment

Results for explosive compounds were below MDLs in all sediment samples at the TOAR-FUDS. Explosives results for sediment samples are presented in Table 4-17.

4.2.2.3 Conclusions for Sediment

Although lead was a common component in most ammunition used at the site, lead results do not exceed site-specific maximum background concentrations. Therefore, sediment within ordnance features at the site appears not to have been impacted by lead. Other metals that appear to have impacted sediment within ordnance features at the site include chromium, copper, and mercury. The risk posed by metals in sediments to human health and the environment (i.e., ecological impacts) is further evaluated in subsection 7.2, where analytical results are compared to applicable regulatory criteria and background or reference values. Explosives do not appear to have impacted sediment at the site.

4.2.3 Surface Water

Surface water samples were collected where surface water was ponding/pooling near target sampling areas (not from flowing streams) and analyzed for metals and explosives. Six surface water samples were collected.

4.2.3.1 Metals in Surface Water

MC surface water sample results for metals are shown in Table 4-18. MC surface water sample results for metals are compared to background concentrations, collected as part of the TYAD ERA in 1997, in Table 4-19. This discussion of analytical results for metals will focus on the following metals based on historical practices at the site: antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. All metal results are screened against applicable criteria in subsection 7.2.

Antimony results were below method detection limits in all surface water samples.

Arsenic was detected in one surface water sample (T11-SW-4252-101), at a concentration of 5.4 micrograms per liter (µg/L). T11-SW-4252-101 was a duplicate sample of T11-SW-4252-001, in which no arsenic was detected.

Beryllium was detected in four surface water samples, with concentrations ranging from 1.5 µg/L to 1.7 µg/L. Beryllium was not detected above MDLs in background surface water samples collected for the TYAD ERA in 1997, but all results from 2004 were below the reporting limit for beryllium (5.00 µg/L) defined in the 1997 report.

Cadmium was detected in one surface water sample (T11-SW-4252-101), at a concentration of 1 µg/L. Cadmium was not detected above MDLs in background surface water samples collected for the TYAD ERA in 1997, but the positive result for T11-SW-4252-101 is below the reporting limit for cadmium (4.01 µg/L) defined in the 1997 report. Also, T11-SW-4252-101 was a duplicate sample of T11-SW-4252-001, in which no cadmium was detected.

Chromium was detected in one surface water sample, T11-SW-4252-001, and its duplicate sample, T11-SW-4252-101, with concentrations of 2.8 µg/L and 3.7 µg/L, respectively.

Chromium was not detected above MDLs in background surface water samples collected for the TYAD ERA in 1997, but concentrations in T11-SW-4252-001 and T11-SW-4252-101 were below the reporting limit for chromium (6 µg/L) defined in the 1997 report.

Copper was detected in five surface water samples, with concentrations ranging from 1.9 µg/L to 11.5 µg/L. Three samples exceeded the mean background concentration at TYAD, but none of the samples exceeded the maximum background concentration.

Lead was detected in five surface water samples, with concentrations ranging from 4.6 µg/L to 31.5 µg/L. All sample results exceed the mean and maximum background concentrations at TYAD. As stated previously, lead balls were used as filler/weight in ammunition used at the site, including 37-mm, 75-mm, 155-mm, and 3-inch A-A shrapnel shells, and lead azide was a primary explosive used for initiation.

Mercury was detected in one surface water sample (T11-SW-4252-001), at a concentration of 0.13 µg/L. Mercury was not detected above MDLs in background surface water samples collected for the TYAD ERA in 1997, but the positive result for T11-SW-4252-001 is below the reporting limit for mercury (0.243 µg/L) defined in the 1997 report. Also, that sample was a duplicate sample of T11-SW-4252-001, in which mercury was not detected above MDLs.

Nickel was detected in three surface water samples at concentrations ranging from 1.4 µg/L to 3.2 µg/L. Nickel was not detected above MDLs in background surface water samples collected for the TYAD ERA in 1997, but all results are below the reporting limit for nickel (34.3 µg/L) defined in the 1997 report. Also, one sample (T11-SW-4252-001) was a duplicate sample of T11-SW-4252-001, in which nickel was not detected above MDLs.

Selenium was detected in one surface water sample (T3-SW-4252-001), at a concentration of 3.8 µg/L. Selenium was not detected above MDLs in background surface water samples collected for the TYAD ERA in 1997, but the result for T3-SW-4252-001 is below the reporting limit for selenium (3.02 µg/L) defined in the 1997 report.

Silver was detected in one surface water sample (RA11-SW-4259-001), at a concentration of 0.33 µg/L. Silver was not detected above MDLs in background surface water samples collected for the TYAD ERA in 1997, but the result for RA11-SW-4259-001 is well below the reporting limit for silver (4.60 µg/L) defined in the 1997 report.

Thallium results were below MDLs in all surface water samples.

Zinc was detected in all six surface water samples, with concentrations ranging from 7 mg/kg to 27.7 mg/kg. Two samples exceeded the maximum background concentration at TYAD.

4.2.3.2 Explosives in Surface Water

Results for explosive compounds results were below MDLs in all surface water samples at the TOAR-FUDS. Explosives results for surface water samples are presented in Table 4-20.

4.2.3.3 Conclusions for Surface Water

Given that lead was a common component in most ammunition used at the site, and lead results exceeded site-specific maximum background concentrations, surface water within ordnance features at the site appears to have been impacted by lead. Zinc also appears to have impacted surface water within ordnance features at the site. The risk posed by metals in surface water to human health and the environment (i.e., ecological impacts) is further evaluated in subsection 7.2, where analytical results are compared to applicable regulatory criteria and background or reference values. Explosives do not appear to have impacted surface water at the site.

4.2.4 Fill Area at Firing Point #1

During the field investigation at TOAR, an area of fill material containing municipal type trash was discovered at FP #1. In addition to this discovery, an empty 55-gallon drum was located on the surface at FP #1. Due to this discovery, PADEP authorized further investigation at FP #1 to properly classify and characterize the site. Specifically, test-pitting was performed to investigate for DMM associated with the FP, and additional chemical characterization was performed.

In addition to the original constituents of concern (metal and explosives), two soil samples collected at the fill area at FP #1 were analyzed for TCL VOCs, TCL SVOCs, pesticides, and PCBs to properly characterize chemical contamination, if any, of the native soil below the respective fill layers. The results for soil samples collected from the test pits at FP #1 are discussed in the following subsections. Results for metals and positive results for all other analytes are presented in Table 4-21. Complete analytical results, including all non-detections, are presented in Appendix N. No MEC or MD were found in the vicinity of FP #1.

4.2.4.1 Metals in Fill Area at Firing Point #1

Antimony was detected in both samples, at concentrations of 0.43 mg/kg and 2.7 mg/kg. The higher result exceeded site-specific maximum background concentrations and maximum background concentrations for Pennsylvania. Lead antimony was used in small arms ammunition at the site.

Arsenic was detected in both samples, at concentrations of 5.3 mg/kg and 25.1 mg/kg. The higher result exceeded the site-specific maximum background concentrations and the mean for Pennsylvania. However, the higher result did not exceed the maximum background concentration for Pennsylvania.

Beryllium was detected in one sample, at a concentration of 0.2 mg/kg. The concentration is below the reporting limit for beryllium (0.5 mg/kg) and below the mean site-specific background concentration.

Cadmium was detected in both samples, at concentrations of 0.92 mg/kg and 0.6 mg/kg. Neither result exceeded site-specific mean or maximum background concentrations, or mean or maximum background concentrations for Pennsylvania.

Chromium was detected in both samples, at concentrations of 7 mg/kg and 9.5 mg/kg. The higher result exceeded site-specific maximum background concentrations, but did not exceed mean or maximum background concentrations for Monroe County or for Pennsylvania.

Copper was detected in both samples, at concentrations of 12.9 mg/kg and 98.8 mg/kg. Both results exceeded site-specific maximum background concentrations. The higher result exceeded maximum background concentrations for Monroe County and for Pennsylvania. The high concentrations of lead found at this site are often associated with higher concentrations of copper.

Lead was detected in both samples, at concentrations of 15.2 mg/kg and 316 mg/kg. Only the higher result exceeded site-specific maximum background concentrations, and maximum background concentrations for Monroe County and for Pennsylvania. Although no MEC or MD were found in the vicinity of FP #1, lead was used extensively at the site. As stated previously, lead balls were used as filler/weight in ammunition used at the site, including 37-mm, 75-mm, 155-mm, and 3-inch A-A shrapnel shells, and lead azide was a primary explosive used for initiation.

Mercury was detected in one sample at a concentration of 0.067 mg/kg. This result did not exceed the site-specific mean background concentration, or the mean background concentration for Pennsylvania.

Nickel was detected in both samples, at concentrations of 15.7 mg/kg and 8.4 mg/kg. While both results exceeded the site-specific maximum background concentrations, neither sample exceeded the maximum background concentration for Monroe County or the mean or maximum background concentrations for Pennsylvania.

Selenium was detected in one sample at a concentration of 0.46 mg/kg. The concentration is below the reporting limit for selenium (0.58 mg/kg) and below the mean site-specific background concentration and the mean background concentration for Pennsylvania.

Silver was detected in both samples, at concentrations of 0.065 mg/kg and 0.11 mg/kg, with both results affected by method blank contamination. Both results are below the reporting limit for silver (0.58 mg/kg) and below the mean site-specific background concentration and the mean background concentration for Pennsylvania.

Thallium results were below MDLs in both soil samples.

Zinc was detected in both samples, at concentrations of 50 mg/kg and 72.5 mg/kg. The higher result exceeded site-specific maximum background concentrations, but did not exceed mean or maximum background concentrations for Monroe County or for Pennsylvania.

4.2.4.2 Explosives in Fill Area at Firing Point #1

Results for explosive compounds were below MDLs in both soil samples collected from test pits at FP #1. MEC was not found in the vicinity of FP #1.

4.2.4.3 Volatiles in Fill Area at Firing Point #1

Acetone was the only VOC detected above MDLs in soil samples collected from test pits at FP #1. Acetone was detected in one sample at a concentration of 91 μg/kg.

4.2.4.4 Semivolatiles in Fill Area at Firing Point #1

Results for SVOCs were below MDLs in both soil samples collected from test pits at FP #1.

4.2.4.5 Pesticides in Fill Area at Firing Point #1

4,4'-DDT was the only pesticide detected above MDLs in soil samples collected from test pits at FP #1. 4,4'-DDT was detected in one sample at a concentration of 0.28 μg/kg, which is only slightly above the minimum detection limit (0.22 μg/kg) and below the reporting limit (2.0 μg/kg). The presence of 4,4'-DDT could be related to past practices at this property.

4.2.4.6 PCBs in Fill Area at Firing Point #1

Results for PCBs were below MDLs in both soil samples collected from test pits at FP #1.

4.2.4.7 Conclusions for Fill Area at Firing Point #1

Overall, the buried municipal trash appeared to be confined within an approximately 140-ft x 50-ft area. No distinguishable odors, visible contamination, or DMM were observed. The empty 55-gallon drum appeared to be an isolated occurrence; no contamination was observed in the vicinity.

Given that lead was a common component in most ammunition used at the site, and lead results exceeded site-specific maximum background concentrations and regional and county-specific maximum background concentrations, soil near FP #1 may have been impacted by lead. Other metals that potentially could have impacted soil near FP #1 include antimony, arsenic, and copper. The risk posed by metals in soil at FP #1 to human health and the environment (i.e., ecological impacts) is further evaluated in subsection 7.2, where analytical results are compared to applicable regulatory criteria and background or reference values. Acetone was the only other compound detected at the fill area at FP #1. No other VOCs, SVOCs, explosives, pesticides, or PCBs appear to have impacted soil in fill areas near FP #1.

4.2.5 Sampling Data QA/QC

This section summarizes the quality assurance/quality control (QA/QC) analyses associated with environmental sampling at the TOAR-FUDS. Sampling was conducted from September 9, 2004 through October 13, 2004. Fifty-five soil/sediment samples, five surface water samples, seven field duplicates, one trip blank and three field blanks comprise the three analytical batches submitted to STL-Pittsburgh and STL-Knoxville for VOCs analyses (SW-846, Method 8260B), SVOCs analyses (SW-846, Method 8270C), pesticides analyses (SW-846, Method 8081A), PCBs analyses (SW-846, Method 8082), explosives analyses (SW-846, Method 8330) and metals/mercury analyses (SW-846, Method 6010B/7471A/7470A).

The QA/QC data review examined the following analytical parameters: data completeness, receipt temperature, holding time, blank analyses, instrument tuning, calibrations, surrogate recoveries, matrix spike/spike duplicate recoveries, laboratory control sample recoveries, internal standards, field duplicates and compound quantitation. All samples were successfully analyzed for all target compounds and are considered usable; however, general deviations from the established QC criteria are outlined below.

For clarification, the following laboratory flagging conventions are defined:

- Organics:
  - J = Detected result was at a concentration below the reporting limit.
  - B = Compound was detected in the associated method blank.
- Inorganics:
  - J = Compound was detected in the associated method blank.

- B = Detected result was between the MDL and the reporting limit.

4.2.5.1 Data Completeness

The data packages were complete and all analyses were performed undiluted.

4.2.5.2 Receipt Temperature

All batches were received at temperatures within 4°±2°C.

4.2.5.3 Holding Time

All sample analysis holding times were met.

4.2.5.4 Blank Analyses

Most method, trip and field blanks were free of compound contamination. Exceptions are outlined below.

Copper was detected in both the soil and surface water method blanks for batch C4J070339. The associated soil sample results were greater than five times the method blank concentration and are considered acceptable as reported. However, the associated surface water sample concentrations were less than five times the blank concentration and should be considered not detected. The associated surface water samples were as follows:

Field Sample ID	Analyte
TOAR-T1-SW-4252-001	Copper
TOAR-T3-SW-4252-001	Copper
TOAR-T6-SW-4252-001	Copper
TOAR-T11-SW-4252-001	Copper

The soil method blank in batch C4J150228 contained nickel, copper, chromium, lead and silver at levels between the MDL and the reporting limits. The following associated sample results were less than five times the blank concentration, and should be considered not detected:

Field Sample ID	Analytes
TOAR-SPBG-4285-001	Nickel
TOAR-SPBG-4285-002	Nickel, Silver
TOAR-SPBG-4285-003	Nickel, Silver
TOAR-SPBG-4285-004	Nickel, Silver
TOAR-GLBG -4285-005	Silver
TOAR-GLBG -4285-006	Silver
TOAR-GLBG -4285-007	Nickel, Silver
TOAR-GLBG -4285-008	Nickel, Silver
TOAR-FP1-TP-4287-004	Silver
TOAR-FP1-TP-4287-007	Silver

The soil, sediment, and surface water method blanks and the field blanks contained beryllium, zinc and copper in batch C4I170285. The following associated samples results were less than five times the blank concentration, and should be considered not detected:

Field Sample ID	Analytes
TOAR-T1-SS-4257-001	Beryllium
TOAR-T1-SS-4257-002	Beryllium
TOAR-T1-SS-4257-003	Beryllium
TOAR-F2A-SS-4257-001	Beryllium
TOAR-F2A-SS-4257-002	Beryllium
TOAR-F2-SS-4257-002	Beryllium
TOAR-F3-SS-4257-001	Beryllium
TOAR-F3-SS-4257-002	Beryllium
TOAR-F5-SS-4257-001	Beryllium
TOAR-F5-SS-4257-002	Beryllium
TOAR-F2A-SS-4257-201	Beryllium
TOAR-F4-SS-4258-001	Beryllium
TOAR-F4-SS-4258-002	Beryllium
TOAR-F4-SS-4258-102	Beryllium
TOAR-T8-SS-4258-001	Beryllium
TOAR-T8-SS-4258-002	Beryllium
TOAR-T8-SS-4258-003	Beryllium
TOAR-T10-SS-4258-001	Beryllium

Field Sample ID	Analytes
TOAR-T10-SS-4258-002	Beryllium
TOAR-T10-SS-4258-003	Beryllium
TOAR-T9-SS-4258-001	Beryllium
TOAR-T9-SS-4258-002	Beryllium
TOAR-T9-SS-4258-003	Beryllium
TOAR-T7-SS-4258-001	Beryllium
TOAR-T7-SS-4258-002	Beryllium
TOAR-T7-SS-4258-003	Beryllium, Zinc
TOAR-T7-SS-4258-103	Beryllium, Zinc
TOAR-T11-SS-4259-001	Beryllium
TOAR-T11-SS-4259-002	Beryllium
TOAR-T11-SS-4259-003	Beryllium, Zinc
TOAR-T6-SS-4259-001	Beryllium
TOAR-T6-SS-4259-002	Beryllium
TOAR-T6-SS-4259-102	Beryllium
TOAR-T6-SS-4259-003	Beryllium
TOAR-T6-SS-4259-201	Beryllium
TOAR-RA11-SD-4259-001	Beryllium, Copper
TOAR-RA11-SW-4259-001	Beryllium
TOAR-RA11-SW-4259-002	Beryllium

4.2.5.5 Instrument Tuning

All VOCs and SVOCs met the 12-hour tuning criteria.

4.2.5.6 Calibrations

Several percent relative standard deviations (%RSDs) and percent differences (%Ds) for VOCs and SVOCs analyses were outside the QC limits; however all compounds were within the expected performance range. No action is required. All other %RSD/%D results were within criteria for the pesticides, PCBs and explosives analyses.

All initial calibration verifications/continuing calibration verifications (ICV/CCVs) and inductively coupled plasma (ICP) interference check standards were within criteria for the metal analyses.

4.2.5.7 Surrogate Recoveries

All surrogate recoveries were within the QC limits for the VOCs, SVOCs, pesticides, PCBs and explosives analyses. No action is required.

4.2.5.8 Matrix Spike/Spike Duplicate Recoveries

The matrix spike/matrix spike duplicate (MS/MSD) recoveries for antimony were below the QC limits for all batches. Samples results for this compound may be biased slightly low.

The MS/MSD recoveries for 2-Amino-4,6-dinitrotoluene and 4-Amino-2,6-dinitrotoluene were below the QC limits for batch C4I170285. In addition, the MS/MSD recoveries for 2-Amino-4,6-dinitrotoluene were below the QC limits for batch C4J070339. Sample results for this compound may be biased slightly low.

All other MS/MSD recoveries and relative percent difference (RPD) results met the QC criteria.

4.2.5.9 Laboratory Control Sample Recoveries

All laboratory control sample/laboratory control sample duplicate (LCS/LCSD) recoveries were within the established QC limits. No action is required.

4.2.5.10 Internal Standards

All internal standards areas and retention times were within the QC limits for the VOCs and SVOCs. No action is required.

4.2.5.11 Field Duplicates

Most sets of field duplicates met reproducibility criteria. Field sample result sets that exceeded the RPD criteria are as follows:

Field Duplicate IDs	Analytes	Action
TOAR-SPBG-4285-001/101	Zinc Nickel Arsenic Cadmium Chromium Lead	Results for these compounds in the field duplicate sample set are considered estimated.
TOAR-T11-SD-4252-001/101	Lead Mercury	Results for these compounds in the field duplicate sample set are considered estimated
TOAR-T11-SW-4252-001/101	Arsenic Lead	Results for these compounds in the field duplicate sample set are considered estimated

4.2.5.12 Compound Quantification

The RDX explosive results were not reported due to interference issues for samples TOAR-FP1-TP-4287-007 (batch C4J150228) and TOAR-T11-SW-4252-001 (batch C4J070339). These results were believed to be below the reporting limit.

In general, the overall data usability and data completeness were considered satisfactory for this sampling activity.

4.2.6 Conclusions for Munitions Constituents

As discussed in subsection 3.2, the intent of the environmental sampling program for this project was to assess the potential of MC contamination resulting from the use of munitions at the TOAR-FUDS, not to provide full site characterization.

Only one explosive was detected above MDLs. HMX was detected in one soil sample collected from FP #2 at a concentration of 0.069 mg/kg, which is slightly above the MDLs (0.048 mg/kg), and well below the reporting limit (0.50 mg/kg). The lack of explosives detected above MDLs in any other samples helps eliminate explosives as potential contaminants of concern.

Several metals were detected in soil, sediment, and surface water samples at concentrations exceeding background levels. Lead was detected in all soil samples, all sediment samples, and five of six surface water samples. Maximum concentrations of lead in soil (611 mg/kg) and surface water (31.5 mg/kg) exceed background or reference values. Copper was also detected in all soil samples, all sediment samples, and five of six surface water samples. Maximum concentrations of copper in soil (167 mg/kg) and sediment (31.5 mg/kg) exceed background or reference values. Finally, antimony was detected in 38 of 44 soil samples, and the maximum concentration of antimony in surface soils (10 mg/kg) exceeds background or reference values.

Environmental samples were collected at biased-high locations (ordnance features such as detonation craters and within impact areas), as shown in Figures 4-3 through 4-13. The presence of some metals (particularly lead) in soils, sediments, and surface water at ordnance features and within impact areas at concentrations that exceed background levels supports the ASR and original CSM.

Analytical results for metals are compared to applicable regulatory criteria and background or reference values in subsection 7.2, and the potential impact of chemicals on human health and the environment (i.e., ecological impacts) is further evaluated in Subsection 7.2.1 and 7.2.2, respectively.

4.3 REVISED CONCEPTUAL SITE MODEL

As discussed in subsection 4.1, in August 2004, based on preliminary data collected during the site investigation, the original CSM for the TOAR-FUDS from the ASR, presented as Figure 3-1 in this report, was amended to reflect site conditions. These amended maps for Park and Game are presented in Figures 4-1 and 4-2, respectively. After the RI was completed, the CSM was further revised and the site was characterized using numerous lines of evidence:

1. Historical information
   a. ASR
   b. EPA EPIC Study
   c. Historical maps
2. UXO recovered during all previous work at the TOAR-FUDS and MD recovered during WESTON activities at the TOAR-FUDS
   a. 1998 HFA TCRA – Park

   b. 1998 HFA Construction Support – TYAD
   c. 2004 WESTON Construction Support – TYAD
   d. 2004 WESTON TCRA – Game
   e. 2004 WESTON site visits
   f. 2004 CENAB site visits
   g. 2004 WESTON RI
3. Artillery range layouts
   a. Historical layouts (USACE provided)
   b. Current range layout standards
4. Visual evidence.
   a. Targets
   b. Powder bunkers
   c. Impact craters
5. Local knowledge.
   a. Local historian
   b. TYAD Environmental Coordinator
   c. Park and Game personnel
   d. Stakeholders
6. MC sampling results.

These lines of evidence are discussed in the following subsections. After the CSM was revised, UXO Estimator Module 2 was used to analyze UXO densities and confirm the CSM. The process by which the original CSM was developed, first amended using initial field data, then finally revised using various lines of evidence, is depicted in the flowchart shown in Figure 4-14. The revised CSM maps for Park and Game are shown in Figures 4-15 and 4-16, respectively. The results summarized in the following subsections are used to evaluate risk related to UXO at the TOAR-FUDS in subsection 7.1.

4.3.1 Historical Information

In September 1995, USACE prepared an ASR for the TOAR-FUDS. The Rock Island District and Defense Ammunition Center and School prepared it for CEHNC (USACE, 1995). The report contains two volumes of information. The first is a factual report of the findings, and the second contains the recommendations. WESTON was only able to review the findings volume.

The ASR summarizes the site, historical ordnance presence, site eligibility for the FUDS program, and results of a visual site inspection, and provides an evaluation of ordnance and other site hazards. In the preparation of the ASR, historical records were searched and site interviews conducted with numerous personnel. The results of the effort are contained in detail in the numerous appendices of the report, and provided the baseline of information used in the development of the initial CSM and plans.

EPA's National Exposure Research Laboratory, through its EPIC Center, analyzes historical records such as aerial imagery, historic and thematic maps, and other cartographic data for environmental site analyses and civil and criminal actions.

Aerial imagery of the TOAR-FUDS was collected from between 1939 and 1999. The photographs are indexed in the EPIC film, and hard copies are currently maintained at WESTON. The EPIC study further supported the ASR findings.

Historical maps not included in the ASR were located in 2003 during the initial project site visit. Several maps were found, but the most important map was a small scale 1920s era hand drawn range map, which was located in the Park Ranger's office. This map, shown in Figure 2-4, was used to validate other maps and known information on FPs and TAs at the TOAR-FUDS. This map detailed the placement of the ranges (firing points, targets and range fans) and was crucial in supporting the characterization of the site. Other maps were also located and used but were not as beneficial as the 1918 map.

4.3.2 UXO Recovered at the TOAR-FUDS

UXO items have been recovered at the TOAR-FUDS during TCRAs, removal actions, construction support projects, and this RI. Documented UXO recovered to date at the TOAR-FUDS include the following:

- 278 UXO recovered in Park during 1998 HFA TCRA. As shown in Figure 4-1, UXO was recovered at the campground and along trails in the Park, which are in areas defined in the original CSM as TAs and RFs.
- 228 UXO recovered on-post at TYAD during 1998 HFA construction support activities. As shown in Figure 4-1, UXO was recovered at the radar facility at TYAD, which is in an area defined in the original CSM as a TA.
- 7 UXO recovered on-post at TYAD during 2004 WESTON construction support activities. As shown in Figure 4-1, UXO was recovered adjacent to the radar facility at TYAD, which is in an area defined in the original CSM as a TA or a RF.
- 1 UXO recovered in Game during 2004 WESTON TCRA. As shown in Figure 4-2, UXO was recovered near 7-Mile Road and Jeep Trail in Game, which is in an area defined in the original CSM as a RF.
- 3 UXO recovered in Park during 2004 WESTON site visit. As shown in Figure 4-1, UXO was recovered near trails in Park, which are in areas defined in the original CSM as TAs or RFs.
- 2 UXO recovered in Park during 2004 CENAB site visit. As shown in Figure 4-1, UXO was recovered near the northern FUDS boundary in Park, which is in an area defined in the original CSM as a RF.
- 78 UXO and 3,367 MD recovered in Park and in Game during 2004 WESTON RI. As shown in Figures 4-1 and 4-2, UXO was recovered in areas defined in the original CSM as TAs and RFs. Empty projectiles were the principal MD that might have been indicative of a UXO presence. Therefore, empty projectiles are shown in orange (as opposed to yellow for other MD) in Figures 4-1, 4-2, 4-15, and 4-16.

All UXO recovered to date at the TOAR-FUDS were within areas defined in the original CSM as TAs or RFs. No DMM was recovered and no disposal pits were found either at the FPs or other locations at the TOAR-FUDS. Therefore no MEC was recovered that could be associated with former activities at FPs. The lack of DMM and disposal pits at the FPs is significant in that it indicates good discipline among the using soldiers and control of munitions. The lack of disposal pits also removes a principal source of MC at the FPs. UXO was not recovered in areas defined as Other Areas. Therefore, to date, all UXO was recovered in areas of expected UXO contamination.

Four UXO were recovered within the BZ in Park. Two items were recovered during the 2004 CENAB site visit, and two items were recovered during the 2004 WESTON RI. The UXO were found inside the northern FUDS boundary, southeast of Lake Watawga, as shown in Figure 4-15. Upon finding the UXO, the minimum separation distance (MSD) for investigative work increased from 200 ft to 2,577 ft, based on the munition with the greatest fragmentation distance (MGFD), the 155-mm M107, as defined in subsection 3.9 of the EE/CA Work Plan. Residential housing is located within 500 ft of the UXO. Therefore, due to safety concerns regarding the residential housing, CENAB halted intrusive investigation. Due to the proximity of UXO and MD to residential housing, and due to fire suppression issues in areas of known or potential UXO contamination, CENAB deemed the area to be in need of a remedial action or a removal action, and halted intrusive characterization efforts. The Lake Watawga Area is shown in Figure 4-15. No UXO are known to have been found outside the FUDS boundary, and the FUDS boundary itself is presumed to be reasonably accurate. Therefore, CENAB established a MSD of 200 ft for investigative work outside the FUDS boundary. Additional investigation north of the FUDS boundary located no additional UXO.

A summary of acreage investigated and UXO recovered during all investigations based on the revised CSM is provided in Table 4-24.

4.3.3 Artillery Range Layouts

4.3.3.1 Generic 155-mm Artillery Range Layout

As discussed in Subsection 4.1, the largest ammunition used at the TOAR-FUDS was 155-mm. Therefore, the generic artillery range layout for 155-mm ammunition was used as a basis for revising the CSM. Figure 4-17 depicts a generic 155-mm artillery range layout. The layout was developed by the Department of the Army, and is described in Pamphlet 385-63, Chapter 11 – Field Artillery. As shown in Figure 4-17, the area surrounding the TA (of variable size) is the impact area (IA). This area is expected to be impacted by ordnance items fired at the TA. Outside the TA and the IA, and within the RF, is the buffer zone (BZ). The BZ is a safety zone where ordnance that does not land in the IA is expected to fall, including short shots, overshots, or shots to the left or right of the IA.

BZs are defined in Figure 4-17 as extending 350 meters in front of the IA, and 725 meters from the rear and sides of the IA. However, as shown in the revised CSM in Figures 4-15 and 4-16, BZs at the TOAR-FUDS were drawn more conservatively, based on the historical artillery range layout described in guidance from USACE Saint Louis District, which is discussed in the following subsection and shown in Figure 4-18.

4.3.3.2 Historical Artillery Range Layouts

USACE Saint Louis District has performed extensive archives research using historical regulations, manuals, and documents to describe general range layouts for small arms, artillery, mortar, etc. According to guidance from USACE Saint Louis, an actual range layout can be constructed only after a site investigation is completed. There are many variables to account for when developing range boundaries, and it is unlikely that all of the data used when the range was originally laid out will be available. Therefore, historical data found during research (maps, aerial photos, documentation, site investigation) should be used to represent the range as accurately as possible. In most cases, however, according to the guidance, the general range layout provided in Figure 4-18 can be used as is.

As shown in Figure 4-18, according to the guidance from USACE Saint Louis District, for a 155-mm artillery range, the BZ should extend out from the FP to the IA to account for short shots, and a 1,000-yard (793-meter) BZ should be added to the rear and sides of the IA to account for overshots or shots to the left or right of the IA. This BZ is more conservative then the BZ defined in Figure 4-17, and was therefore used to draw the BZs shown in Figures 4-15 and 4-16 in the revised CSM at the TOAR-FUDS.

4.3.4 Visual Evidence

Visual evidence was collected throughout the RI to locate UXO and to support characterization of the TOAR-FUDS for MEC. Visual evidence used to support site characterization for MEC consisted primarily of the presence or absence of targets (i.e., wagons) and/or cratering in IAs and in BZs.

Field notes recorded by USRADS crew members while surveying DGM grids for investigation during the RI indicated that craters were found throughout grids surveyed in Targets #7, #8, #9, #10, and #11 in Game, and Targets #2 and #3 in Park, which supports the characterization of those areas as IAs. Survey field notes are provided in Appendix F. (Note that due to the soil composition, which was very rocky with boulders with minimal overburden, craters formed by the explosion of munitions did not sluff and refill, but rather stayed in tact as a crater.) Also, no visual evidence of mass cratering was noted during investigation in BZs and Other Areas.

Remnants of targets (the remaining metal portion of the wood/metal wagons used as targets) were also observed in each target area by field crews and at Target #4 during the initial RI/FS project site visit by WESTON in 2003. The remnants varied in condition from intact to pieces of metal that had been subjected to shrapnel rounds and high explosives.

Powder bunkers (intact or remains) were also noted in the vicinity of the FPs described in the initial CSM and in historical data. The presence of these bunkers allows for more precise placement of the FPs, which in turn allows for accurate revision of the CSM: using a precise FP and target location, the dividing line for buffer and other areas is more well-defined.

Photographs taken at the site of target remnants, powder bunkers, and impact areas can be found in the Visual Evidence folder of the photo log provided in Appendix H.

4.3.5 Local Knowledge

Extensive local knowledge was supplied by area residents, the local historian, PGC and DCNR employees, and the TYAD Environmental Coordinator. Of particular help was one DCNR employee, who has lived in the area for years and has hiked nearly the entire site (both Park and Game). He was instrumental in providing information on where use occurred, what might be found and was able to either lead field crews to the exact locations or highlight the area on a map. In all instances his data was accurate. This information was used to focus investigations, eliminate unnecessary investigations (e.g., across the southern region of Game), and refine the CSM.

The local historian and the TYAD Environmental Coordinator also provided historical information on potential areas of concern and the items that were used during the periods of time the site was active. The TYAD Environmental Coordinator also supported the project RI and site characterization efforts with additional historical photographs and information from the TYAD archives.

The last source of local knowledge came from local, long term residents. At all public meetings (numerous meetings were held during the preparation for and the conduct of the RI), maps were available to residents and they were queried for any information they may have gained about targets, munitions use, etc during their time in the area. Much of this information was provided by hunters who spend many days in the Game preparing for or participating in hunting season. This information was recorded on the working maps and then used to continue refining the site characterization results.

4.3.6 Munitions Constituents Sampling Results

As discussed in subsection 3.2, the intent of the environmental sampling program for this project was to evaluate the presence of MC contamination and help characterize the site for MEC, not to provide full site characterization for MC.

Only one explosive was detected above MDLs. However, several metals were detected in soil, sediment, and surface water samples at concentrations exceeding background levels. Lead was detected in all soil samples, all sediment samples, and five of six surface water samples. Maximum concentrations of lead in soil (611 mg/kg) and surface water (31.5 mg/kg) exceed background or reference values. Copper was also detected in all soil samples, all sediment samples, and five of six surface water samples. Maximum concentrations of copper in soil (167 mg/kg) and sediment (31.5 mg/kg) exceed background or reference values. Finally, antimony was detected in 38 of 44 soil samples, and the maximum concentration of antimony in surface soils (10 mg/kg) exceeds background or reference values.

Environmental samples were collected at biased-high locations (ordnance features such as detonation craters and within impact areas). The presence of some metals (particularly lead) in soils, sediments, and surface water at ordnance features and within impact areas at concentrations that exceed background levels supports the revised CSM.

4.3.7 Revising the CSM

Based on the field data collected during the RI and during previous investigations at the TOAR-FUDS, and all other lines of evidence, revisions to the CSM were deemed necessary to account for high densities of UXO and MD recovered in some areas, and to account for the extensive cratering observed in some areas. To revise the CSM, TAs were first conservatively redrawn to include high densities of UXO, MD indicative of a potential UXO presence (empty projectiles), and heavily cratered areas. The TA boundaries were drawn to include the expected distribution of all UXO at a target, per U.S. Army Field Manual (FM) 6-40, Marine Corps Warfighting Publication (MCWP) No. 3-16.4, “Tactics, Techniques, and Procedures for Field Artillery Manual Cannon Gunnery” (U.S. Army, 1999). The TAs were shaped to closely resemble the generic TAs shown in Figure 4-17, and were aligned in the general direction of the applicable FPs. Then, using the artillery range layout shown in Figures 4-17, IAs were delineated at distances of 240 meters, 160 meters, and 32 meters from the front, rear, and side borders of the TAs, respectively. Finally, using the artillery range layout shown in Figure 4-18, BZs were delineated at 1,000 yards from the boundary of the IAs. It should be noted that due to the use of shrapnel rounds (which are often times used for final protective fires or last line of defense) BZs cannot include safe overhead areas between FPs and TAs. Based on the revised CSM, shown in Figures 4-15 and 4-16, all UXO recovered to date at the TOAR-FUDS are within expected areas of contamination (IAs and BZs). The distribution of items based on the revised CSM is summarized in Tables 4-22 and 4-23.

4.3.7.1 UXO Recovered Outside of Impact Areas

By the nature of range design and layout, the BZ is designed to provide a safety “buffer” for munitions that do not behave as expected. During the normal use of artillery, if all items function exactly as designed, 100% of the items would land within the target/impact areas. However, due to the nature of military munitions, not all items function as designed:

- Propellants may not burn completely, which would cause a projectile to land short of the expected area. (This is likely the cause of the single UXO recovered east of Target 7 in Game during the RI.)

- Excess propellant may be inadvertently placed in the munition, which might cause a projectile to land beyond the target/impact area. (This is likely the cause of the UXO recovered southwest of Target 9 and 10 in Game during the RI, and the UXO recovered west of Target 3 in Park during the HFA TCRA.)

- Artillery procedures anticipate a 5% error in aiming due to either human or mechanical errors, such as incorrect aiming (human error) or variations due to mechanical wear on the artillery piece. In either case, the result could be isolated UXO from projectiles that miss the target/impact area and land in the BZ.

Whether because of malfunction of the munition or because of human/mechanical error, the anticipated quantity of UXO that is expected to land in the BZ is extremely small. The highest probability for locating UXO in the BZ is in the immediate vicinity of the target/impact areas. As you move further away from defined target/impact areas, the probability of finding UXO decreases. This statement and principal is supported by the low density of UXO finds in the BZ and by the fact that UXO that were located in BZs were recovered in close proximity to known target/impact areas.

At the TOAR-FUDS, another factor that was considered when evaluating UXO recovered in BZs is the human influence on UXO over the years. People actively sought out UXO and MD in the 1930s through the 1950s in order to recover the high value brass/bronze rotating bands, which are an integral piece of the munition and can be removed and sold as high value scrap. This was evidenced by the fact that almost all UXO and MD recovered at the TOAR-FUDS during the RI were missing the rotating band. Because people interacted with UXO and MD at the site, it is possible that scrap hunters and/or souvenir collectors picked up and moved UXO or MD from the place it landed (the impact/target area) and moved it to another location (the buffer zone or beyond). This is likely the cause of the single UXO recovered at the intersection of 7-Mile Road and Jeep Trail in Game during the WESTON TCRA, and the UXO recovered along the Blue Trail in Park during the HFA TCRA.

4.3.7.2 UXO Density and UXO Estimator Module 2

As discussed in Subsection 4.1.2.5 and summarized in Table 4-10, UXO density was calculated for the amended CSM using the acreage investigated (using DGM and IAR data, separately) and the number of UXO found. After the CSM was revised, UXO density was recalculated for the revised CSM. The area investigated based on the revised CSM is presented in Table 4-25, and UXO densities for the revised CSM are summarized in Table 4-26.

As discussed in subsection 3.1.1.1, UXO Estimator, a statistical analysis tool developed by CEHNC, was used to determine the number of acres to be investigated using DGM methods to locate anomalies that were probable munitions within the RFs, TAs, and Other Areas. There are three modules in the UXO Estimator Program:

- Module 1: Develop a Sampling Plan.
- Module 2: Analyze Field Data.
- Module 3: Unit Conversion.

Module 1 was used to calculate the minimum number of acres to be investigated using DGM methods in each AOI at the TOAR-FUDS. Module 1 requires three input values:

- Size of AOI (in acres) – The total size of the area to be investigated.
- Target density – An assumed level of UXO presence throughout the AOI, normally stated as UXO per acre. At the TOAR-FUDS, the target density was chosen to be 0.5 UXO/acre, as described in Section 3.1.1.1.
- Confidence level – The degree to which a calculated statistic meets or compares to some measure, such as target density. The default value of 0.95 (or 95%) was used at the TOAR-FUDS, as described in Section 3.1.1.1.

A target density of 0.5 UXO/acre was used for the entire site, along with the default confidence level of 0.95 (or 95%). UXO Estimator calculated that a minimum of 6 acres must be investigated in the RFs, TAs, and Other Areas to achieve a 95% confidence level for each area based on the target density of 0.5 UXO/acre, as summarized in Table 3-3.

After the RI was completed, Module 2 of UXO Estimator was used to analyze the UXO density data collected in the field and to confirm the CSM. Module 2 requires five input values:

- Size of AOI (in acres) – The total size of the area to be investigated.
- The number of acres actually investigated – At the TOAR-FUDS, the acres investigated by either DGM or by IAR (but not combined).
- The number of UXO found – At the TOAR-FUDS, the number of UXO found by either DGM or by IAR (but not combined).
- Target density – An assumed level of UXO presence throughout the AOI, normally stated as UXO per acre. At the TOAR-FUDS, the target density was chosen to be 0.5 UXO/acre, as described in Section 3.1.1.1.
- Confidence level – The degree to which a calculated statistic meets or compares to some measure, such as target density. The default value of 0.95 (or 95%) was used at the TOAR-FUDS, as described in Section 3.1.1.1.

Using the input values, UXO Estimator Module 2 determines if field sampling was adequate to meet the target density at the given confidence level. If field sampling is deemed adequate, Module 2 returns three (3) results:

1. The actual density level (in UXO per acre) indicated by the field sampling data at the assumed confidence level (usually 95%). This result is accompanied by a statement that the density level is within the target UXO density assumed.
2. The actual confidence level for the field data at the target UXO density value.
3. The average (or mean) UXO density level expected in the AOI based on the actual field sample data.

If field sampling is deemed inadequate to meet the target density at the given confidence level, Module 2 returns four (4) results:

1. The user is informed of the actual confidence level of the field data as compared to the target density. This confidence level will of course be less than the assumed confidence level for which Module 2 was run.
2. The average (or mean) UXO density level expected in the AOI based on the actual field sample data.
3. The user is informed that sampling was inadequate to meet the target density at the assumed confidence level, and then states the actual density at this confidence level.
4. The number of additional acres required for sampling with no additional UXO found, in order to meet the target density, is returned.

The results calculated by UXO Estimator Module 2 for both DGM and IAR data for the revised CSM at the TOAR-FUDS are presented in Table 4-27. DGM data was principally considered when interpreting the output from Module 2. The results for DGM data can be summarized as follows:

- Other Areas – Confidence levels (95% for target density of 0.5 UXO/acre) are met for the target density using DGM data in both Park and Game. There is a 99.00% and 99.89% certainty that less than 0.5 UXO/acre is present in Other Areas in the Park and Game, respectively, and no additional investigation is required to characterize the areas. This output from Module 2 agrees with the information derived from the generic artillery range layouts, the ASR, and the data from previous investigations.

- Buffer Zones – Confidence levels (95% for target density of 0.5 UXO/acre) are met for the target density using DGM data in Park, but are not met in Game. There is a 98.85% certainty that less than 0.5 UXO/acre is present in the BZ in Park. There is an 83.01% certainty that less than 0.5 UXO/acre is present in the BZ in Game, which means that additional investigation may be warranted to confirm that UXO densities are less than 0.5 UXO/acre. However, other factors should be considered in order to adequately characterize the BZ in Game, including the following:

    - Visual evidence – No visual evidence of mass cratering was noted during investigation in BZs, which indicates the areas are not TAs or IAs.

    - Generic artillery range layouts – As discussed in subsection 4.3.1, the artillery range layouts shown in Figures 4-17 and 4-18 were developed by USACE based on historic artillery range data. These layouts were used to develop the BZs in the revised CSM for the TOAR-FUDS.

    - Actual UXO density and average UXO density expected – In Game, two UXO were found in the BZ using DGM, therefore the actual density is 0.208, as shown in Table 4-26. The average density expected as calculated by UXO Estimator Module 2 is 0.311. Both densities are less than the target density of 0.5. Therefore, while the confidence levels are not met using DGM according to Module 2, the average densities expected fall within the target density.

    - Wet areas – Approximately 25% of the TOAR-FUDS is covered by wet areas (lakes, ponds, streams, wetlands, etc.). Approximately 1,519 acres in the buffer zone in Game are considered wet areas. As discussed in Section 3, investigation for UXO is not practicable in wet areas. Therefore, the extent of wet areas in the BZs prevented the collection of additional investigation data in some areas.

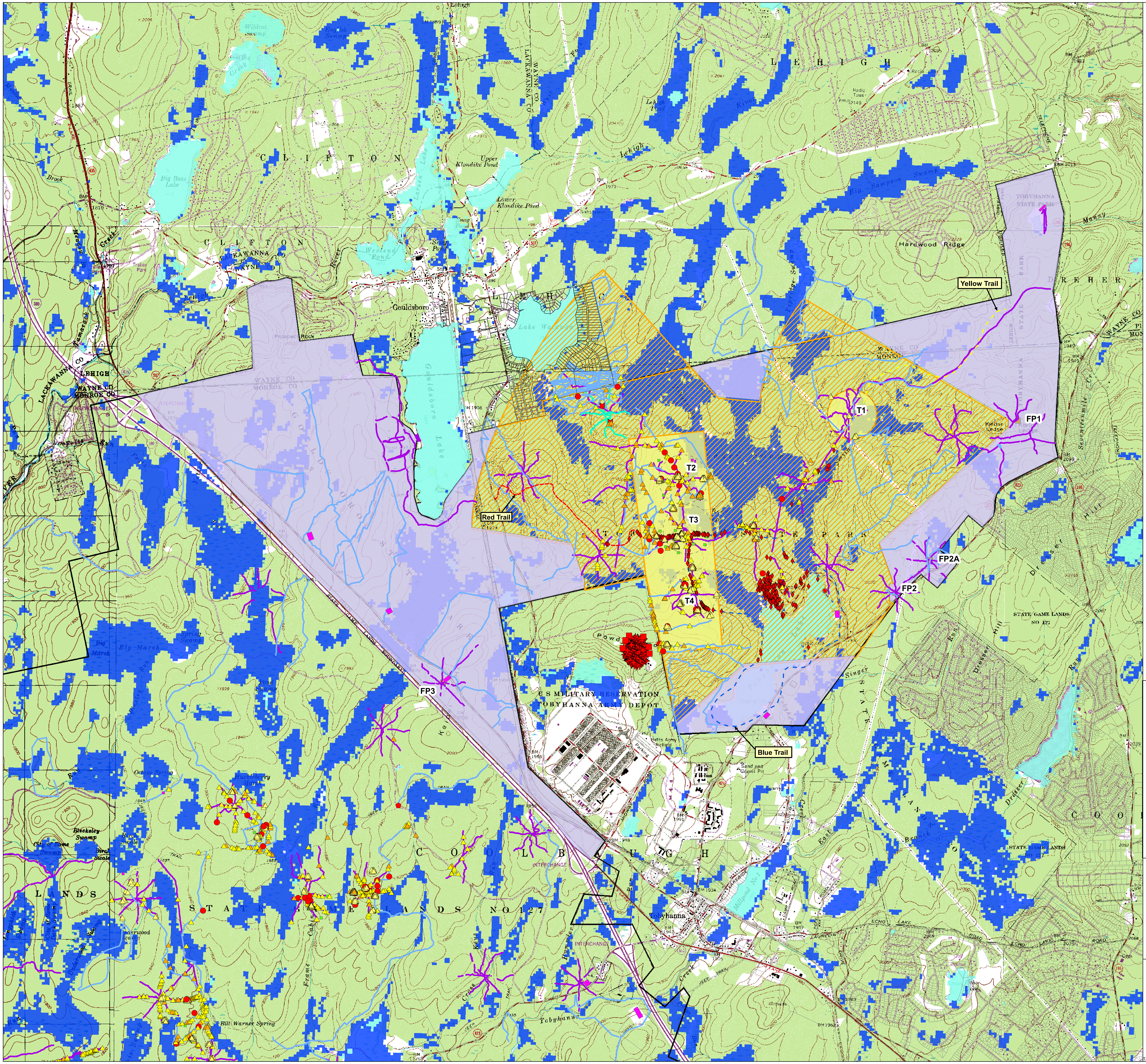
    - UXO recovered in buffer zones during previous investigations – One UXO was recovered in the BZ in Game during the 2004 WESTON TCRA. No other UXO have been recovered in the BZ in Game during previous investigations. In general, UXO recovered in BZs at the TOAR-FUDS have been recovered in the vicinity of IAs. This is indicative of the fact that UXO density in BZs is expected to vary based on proximity to IAs. Also, the UXO recovered at the intersection of 7-Mile Road and Jeep Trail in Game during the WESTON TCRA and the UXO recovered along the Blue Trail in Park during the HFA TCRA were likely picked up and moved by scrap hunters and/or souvenir collectors from the place they landed (the impact/target area) to the location where they were recovered (with the rotating band missing).

- MD recovered in buffer zones during the RI – 167 MD were recovered in the Park BZ during the RI, and 315 MD were recovered in the Game BZ during the RI. The locations and densities of MD recovered, and MD indicative of a UXO presence (empty projectiles), were considered in the development of the TAs and the IAs in both Park and Game.

- Impact Areas – Confidence levels (95% for target density of 0.5 UXO/acre) are not met for the target density using DGM data in both Park and Game. That is, there is a 0% certainty that less than 0.5 UXO/acre is present in IAs in Park and Game. Also, average UXO densities expected are well above the target density of 0.5. This output from Module 2 agrees with the information derived from the generic artillery range layouts, the ASR, and the data from previous investigations.

- Lake Watawga Area – A minimal number of acres were investigated intrusively using DGM methods in the Lake Watawga area due to safety concerns. Therefore, UXO Estimator Module 2 was not used to analyze UXO density in the Lake Watawga area. Other factors such as UXO recovered in the Lake Watawga area during previous investigations and public safety, as discussed in Subsection 4.3.2, are of greater consequence when characterizing the Lake Watawga area and evaluating risk related to UXO.

The uncertainty associated with the use of UXO Estimator is discussed in Section 9.



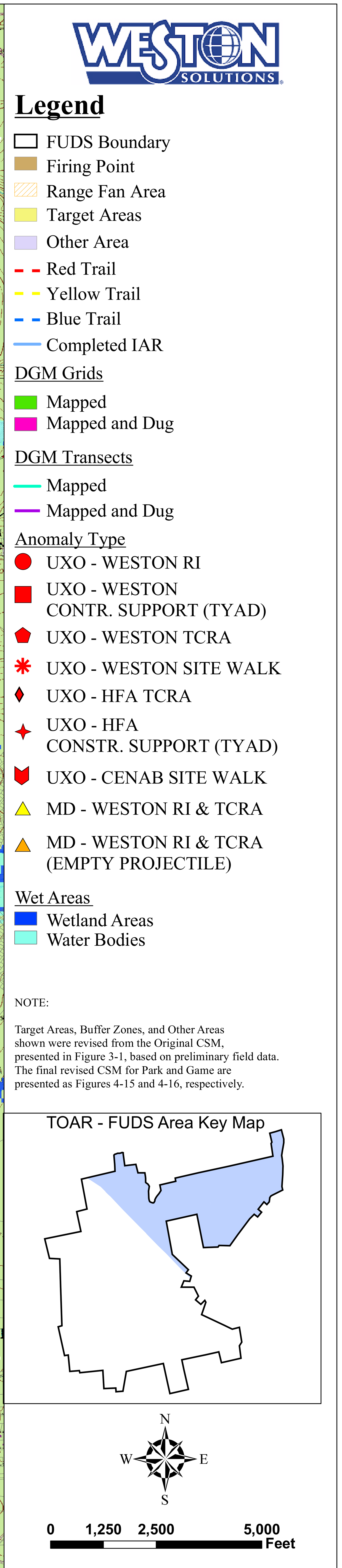


Figure 4-1
UXO Items Found
Park

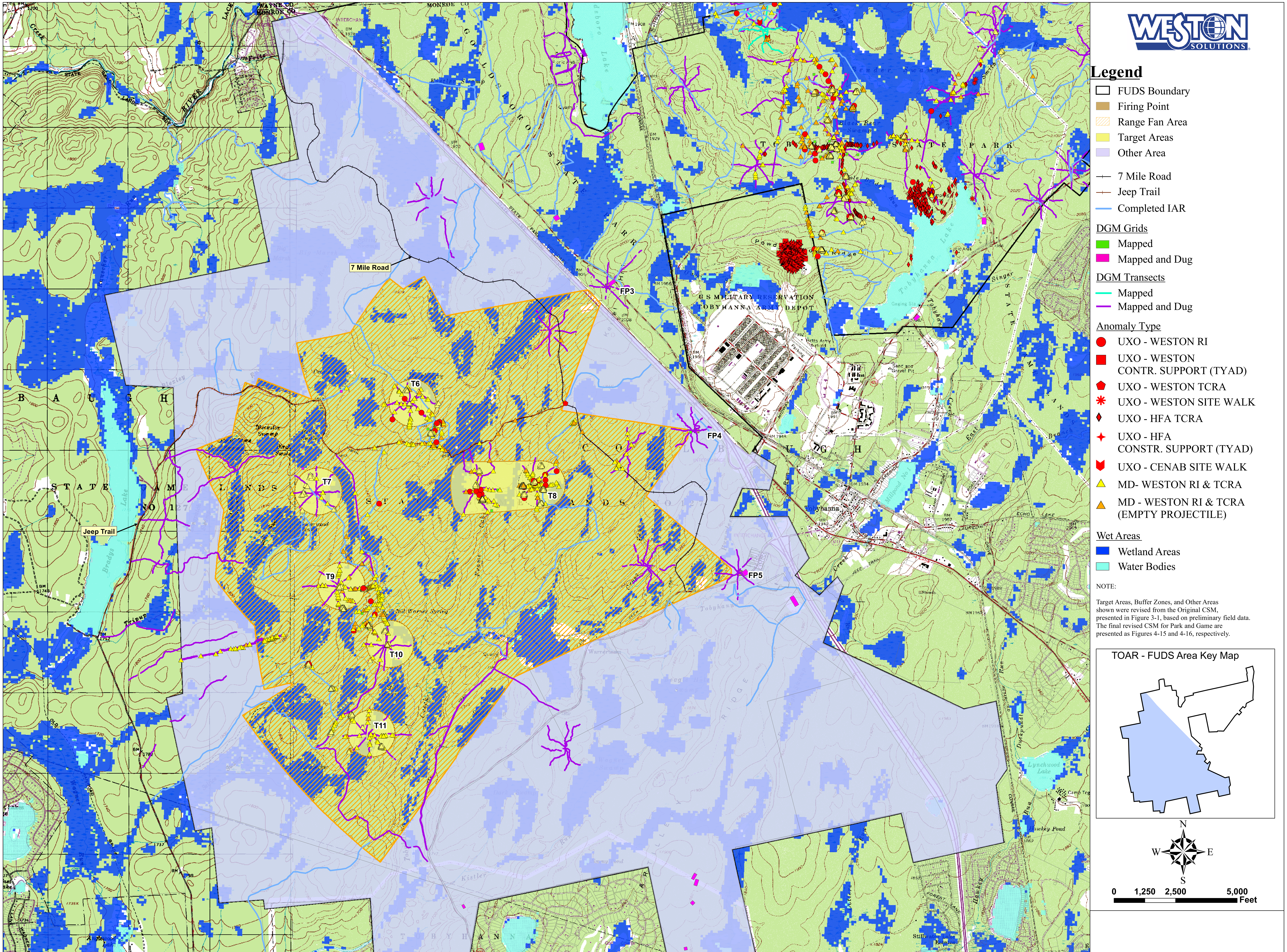


Figure 4-2
UXO Items Found
Game

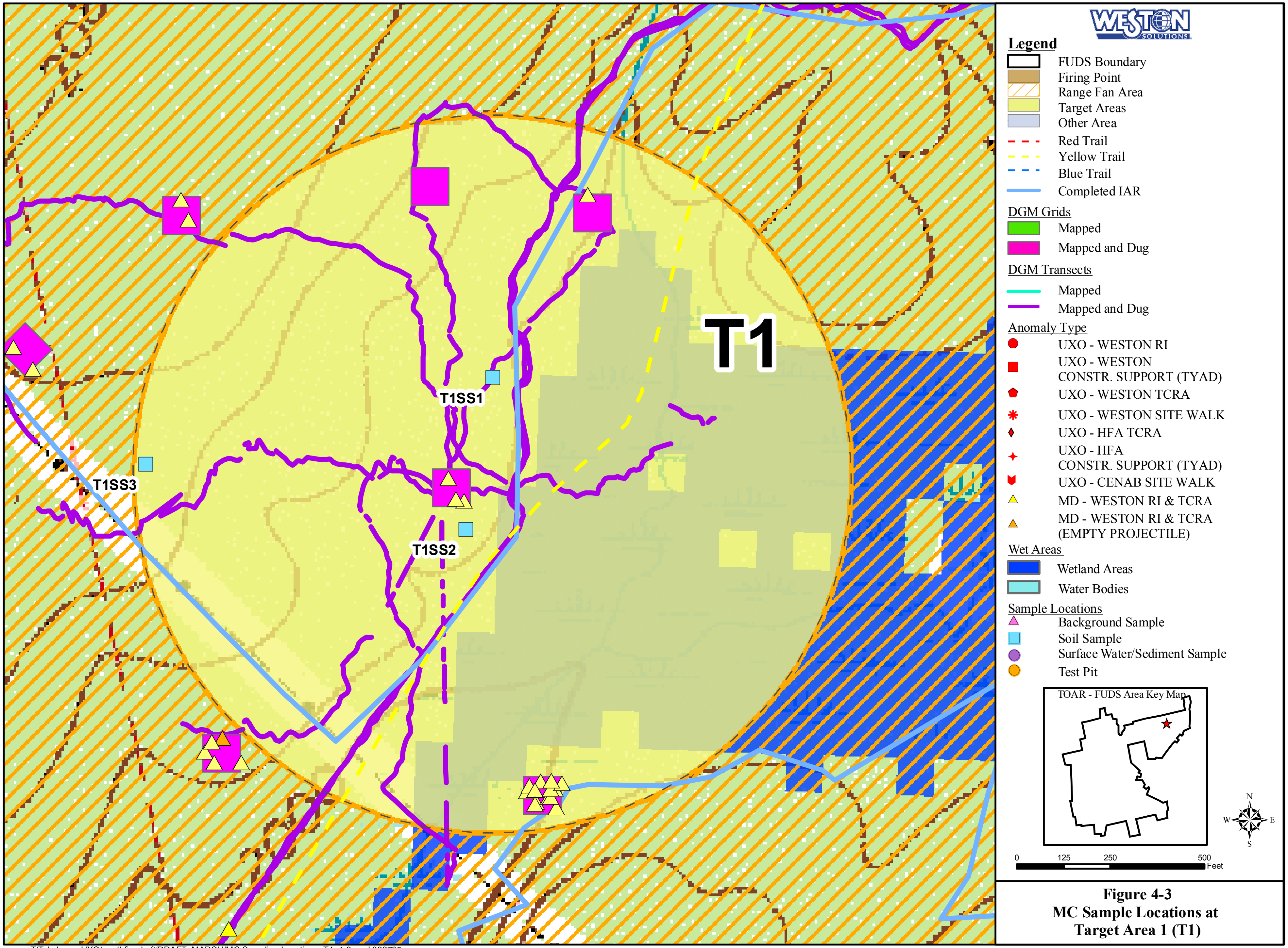


Figure 4-3
MC Sample Locations at Target Area 1 (T1)

T/TobyhannaUXO/mxd/rfis_draft/DRAFT_MARCH/MC Sampling Locations_T1_4-3.mxd 062705

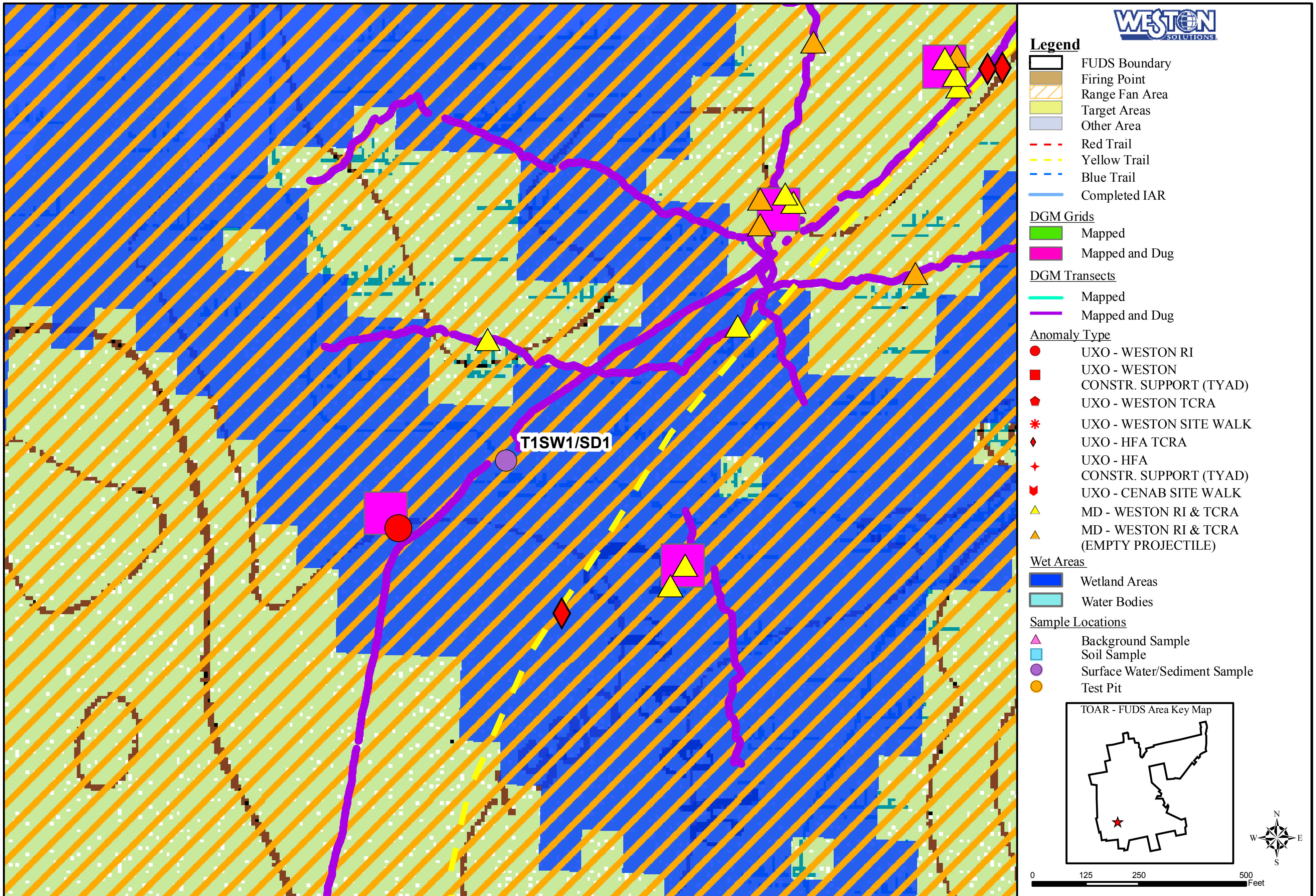


Figure 4-4
MC Sample Locations at T1SW1/SD1

T/TobyhannaUXO/mxd/rfis_draft/DRAFT_MARCH/MC Sampling Locations_T1SW1.mxd 062905

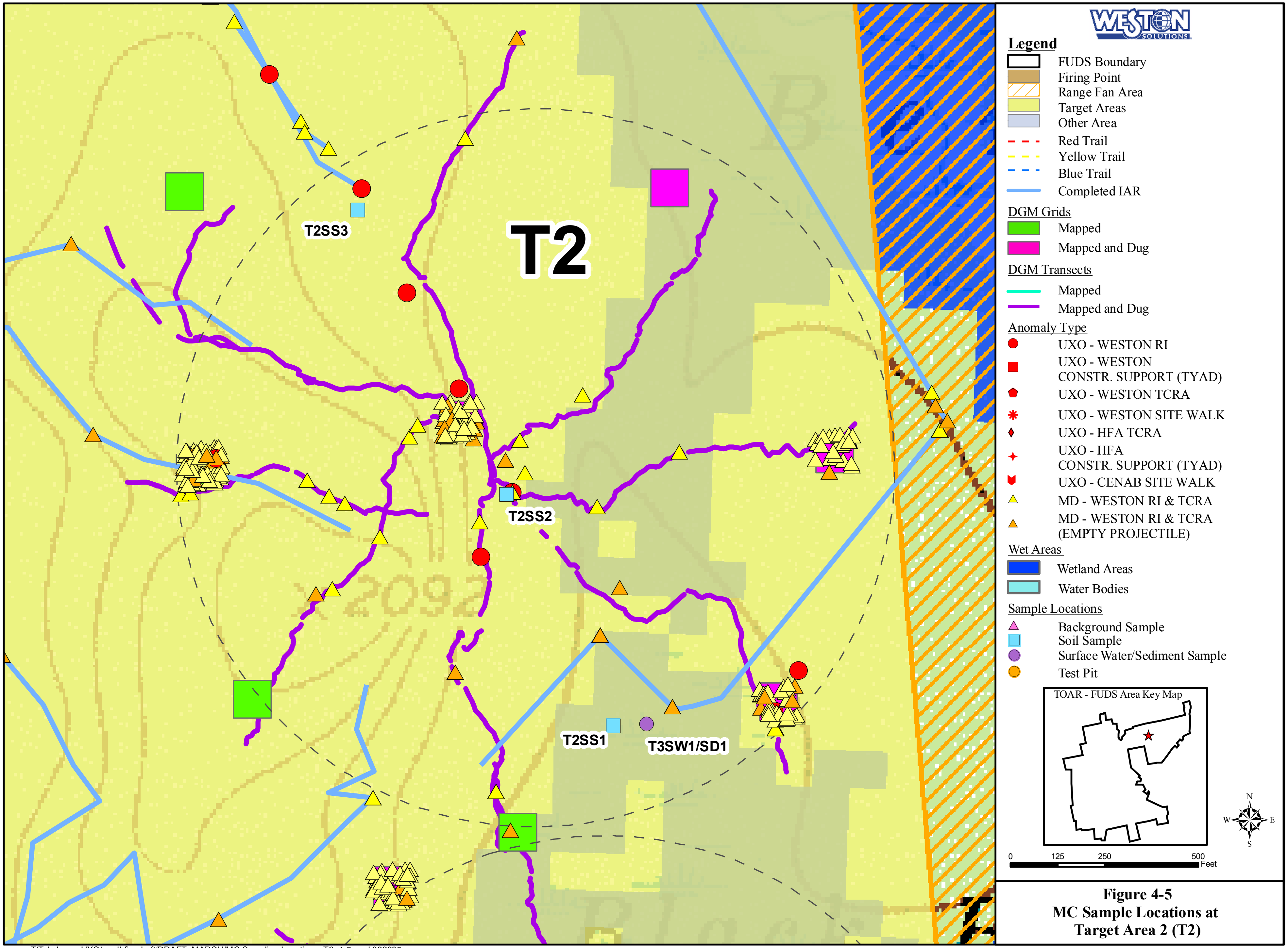


Figure 4-5
MC Sample Locations at
Target Area 2 (T2)

T/TobyhannaUXO/mxd/rfis_draft/DRAFT_MARCH/MC Sampling Locations_T2_4-5.mxd 062905

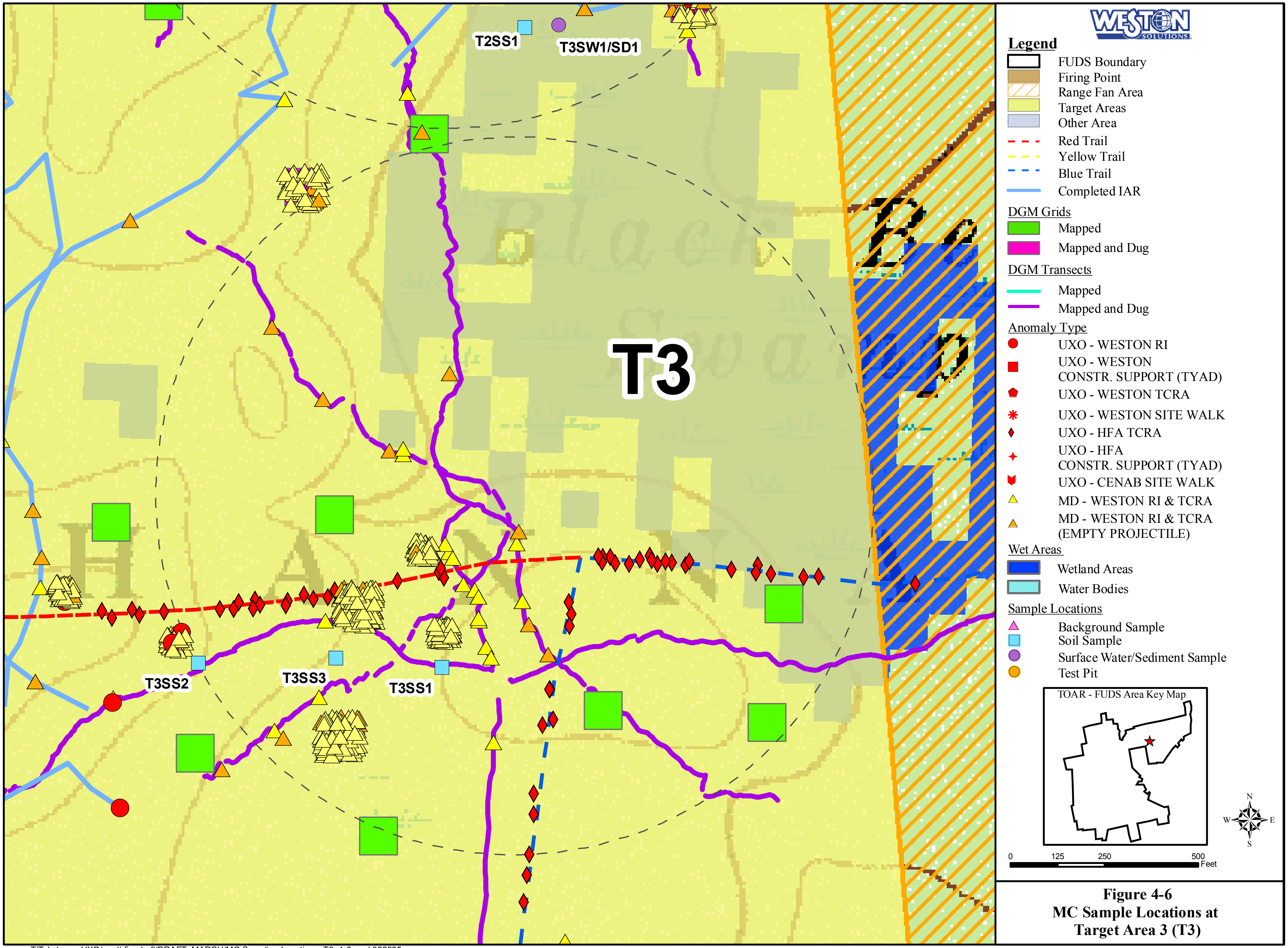


Figure 4-6
MC Sample Locations at
Target Area 3 (T3)

T/TobyhannaUXO/mxd/rfis_draft/DRAFT_MARCH/MC Sampling Locations_T3_4-6.mxd 062905

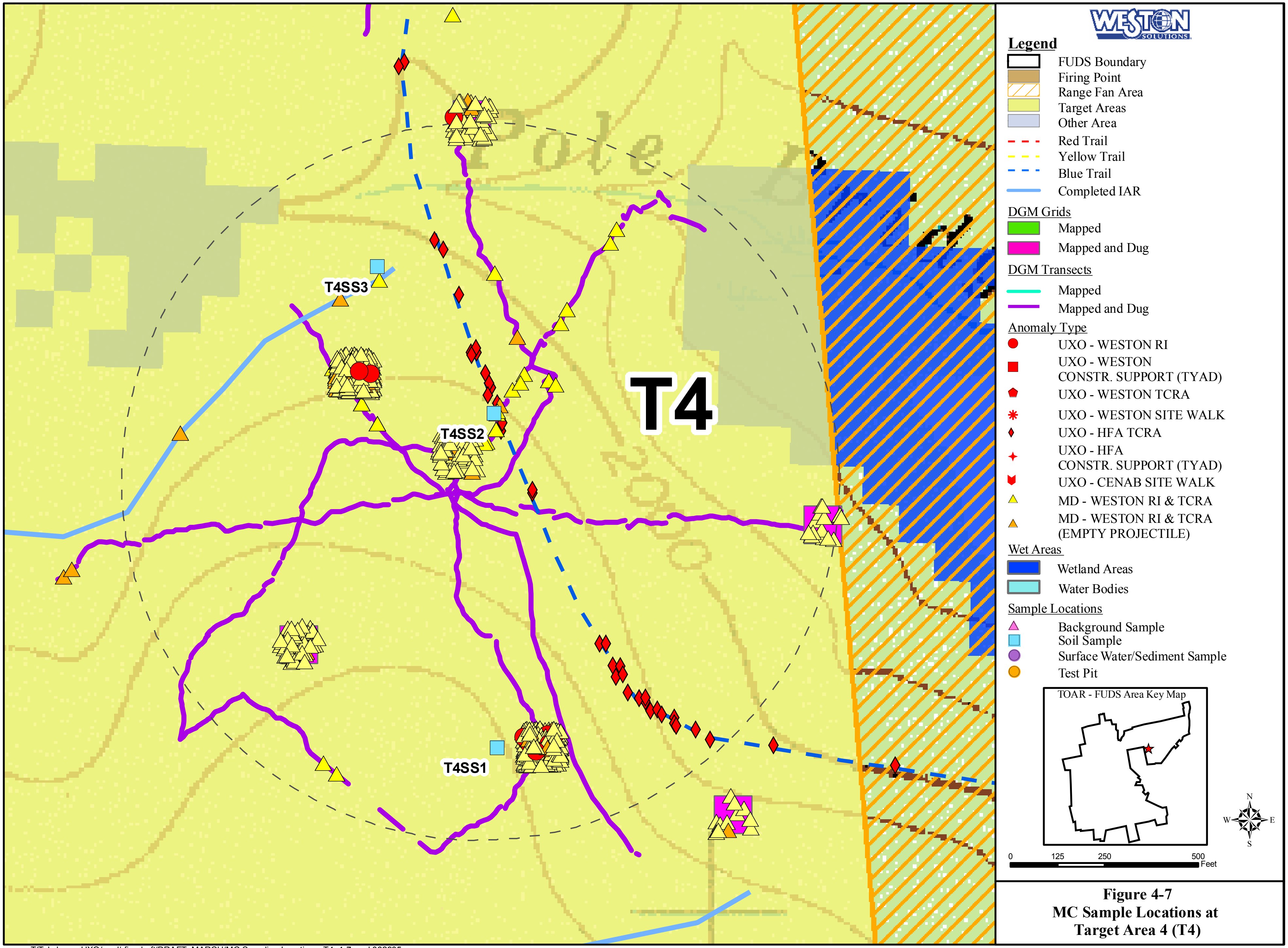


Figure 4-7
MC Sample Locations at Target Area 4 (T4)

T/TobyhannaUXO/mxd/rfis_draft/DRAFT_MARCH/MC Sampling Locations_T4_4-7.mxd 062905

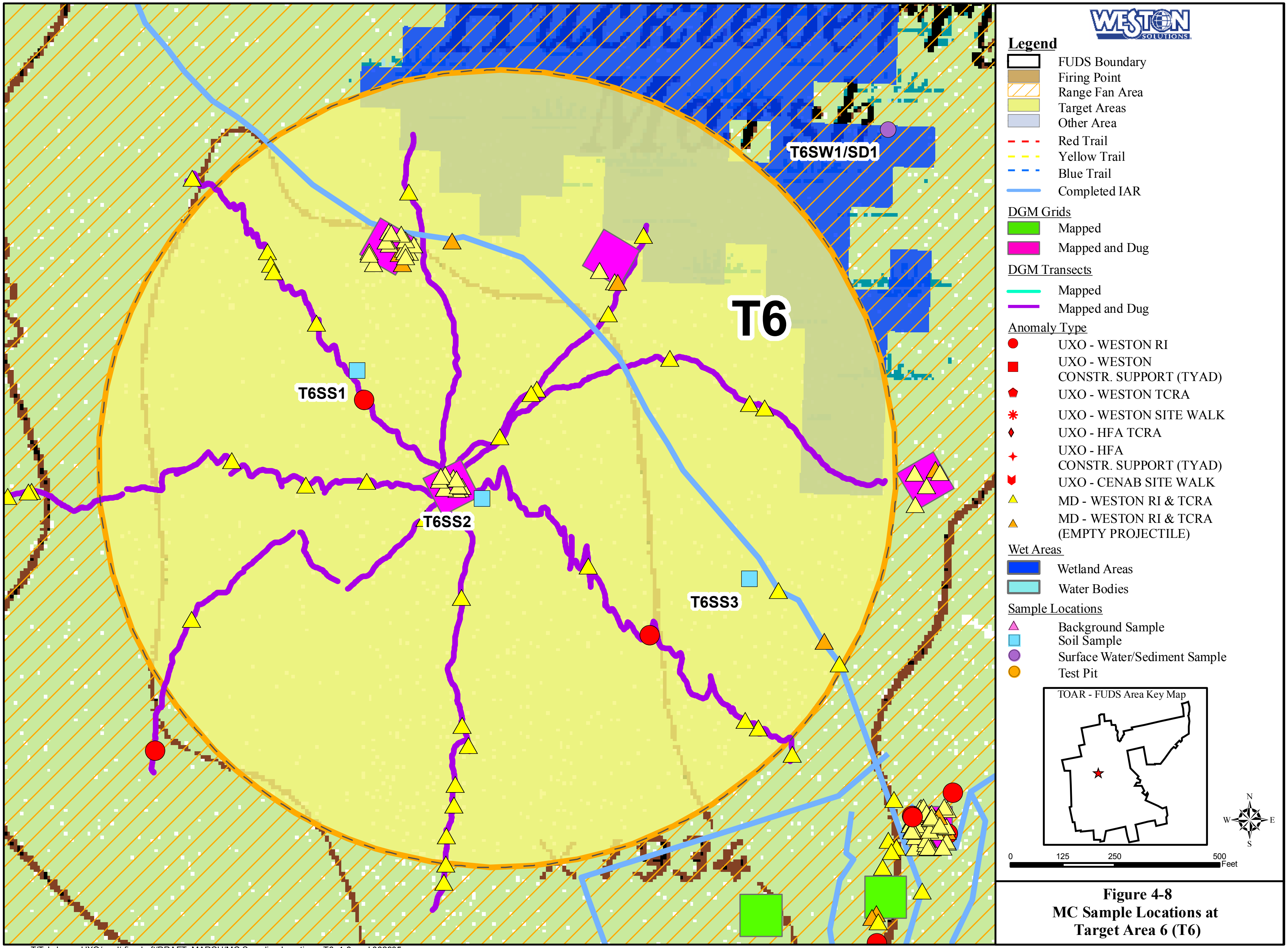


Figure 4-8
MC Sample Locations at Target Area 6 (T6)

T/TobyhannaUXO/mxd/rfis_draft/DRAFT_MARCH/MC Sampling Locations_T6_4-8.mxd 062905

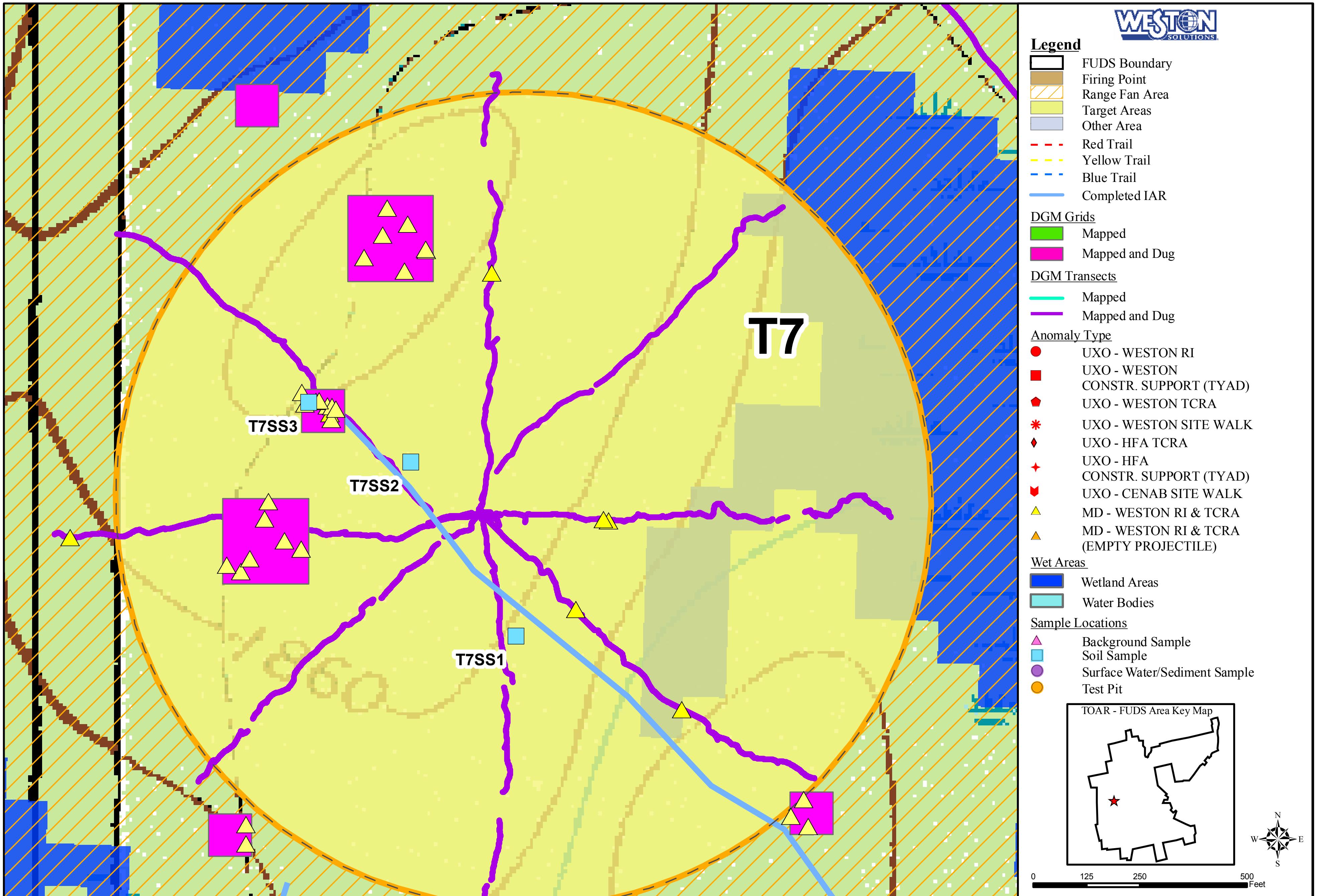


Figure 4-9
MC Sample Locations at Target Area 7 (T7)

T/TobyhannaUXO/mxd/rfis_draft/DRAFT_MARCH/MC Sampling Locations_T7_4-9.mxd 062905

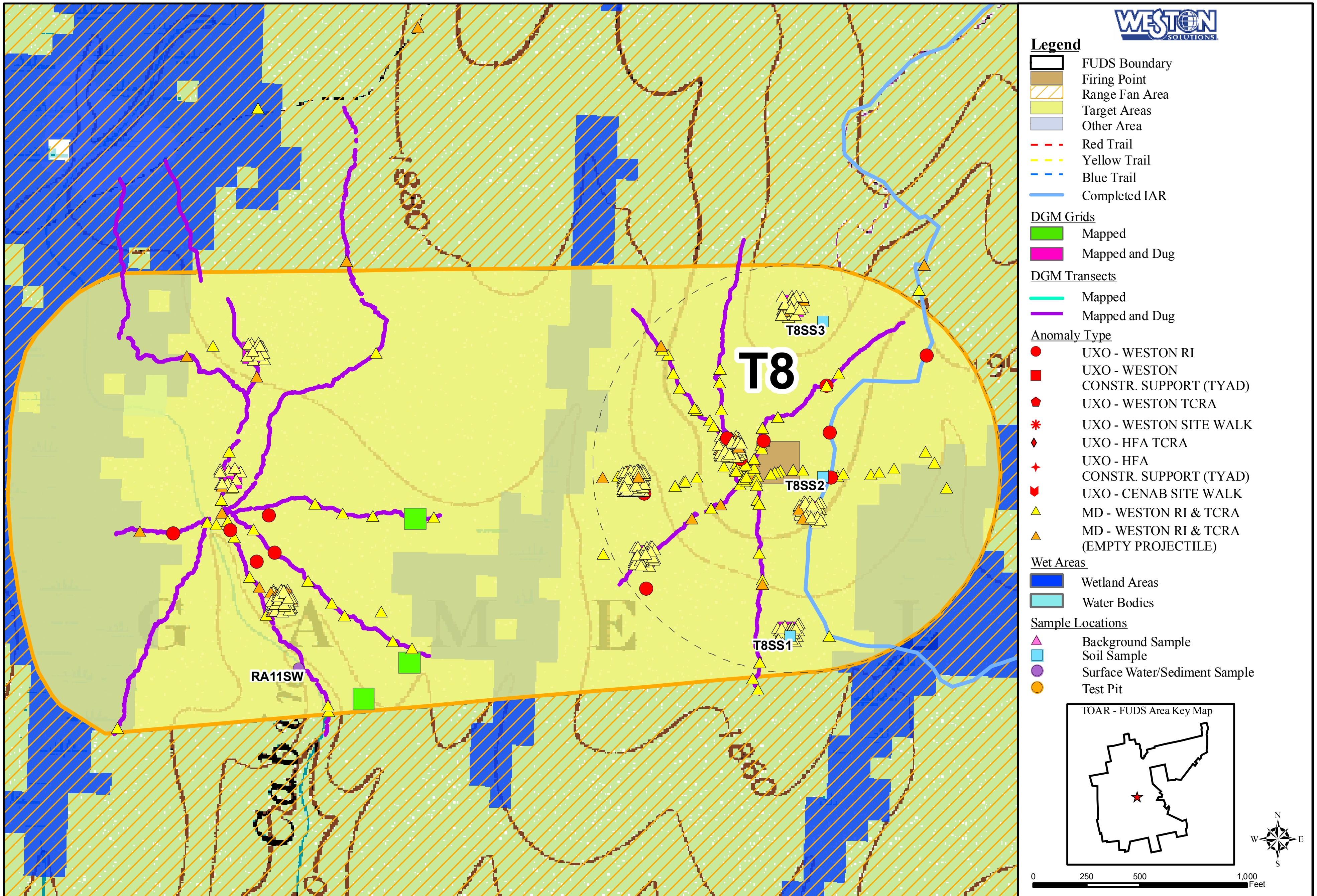


Figure 4-10
MC Sample Locations at Target Area 8 (T8)

T/TobyhannaUXO/mxd/rfis_draft/DRAFT_MARCH/MC Sampling Locations_T8_4-10.mxd 062905

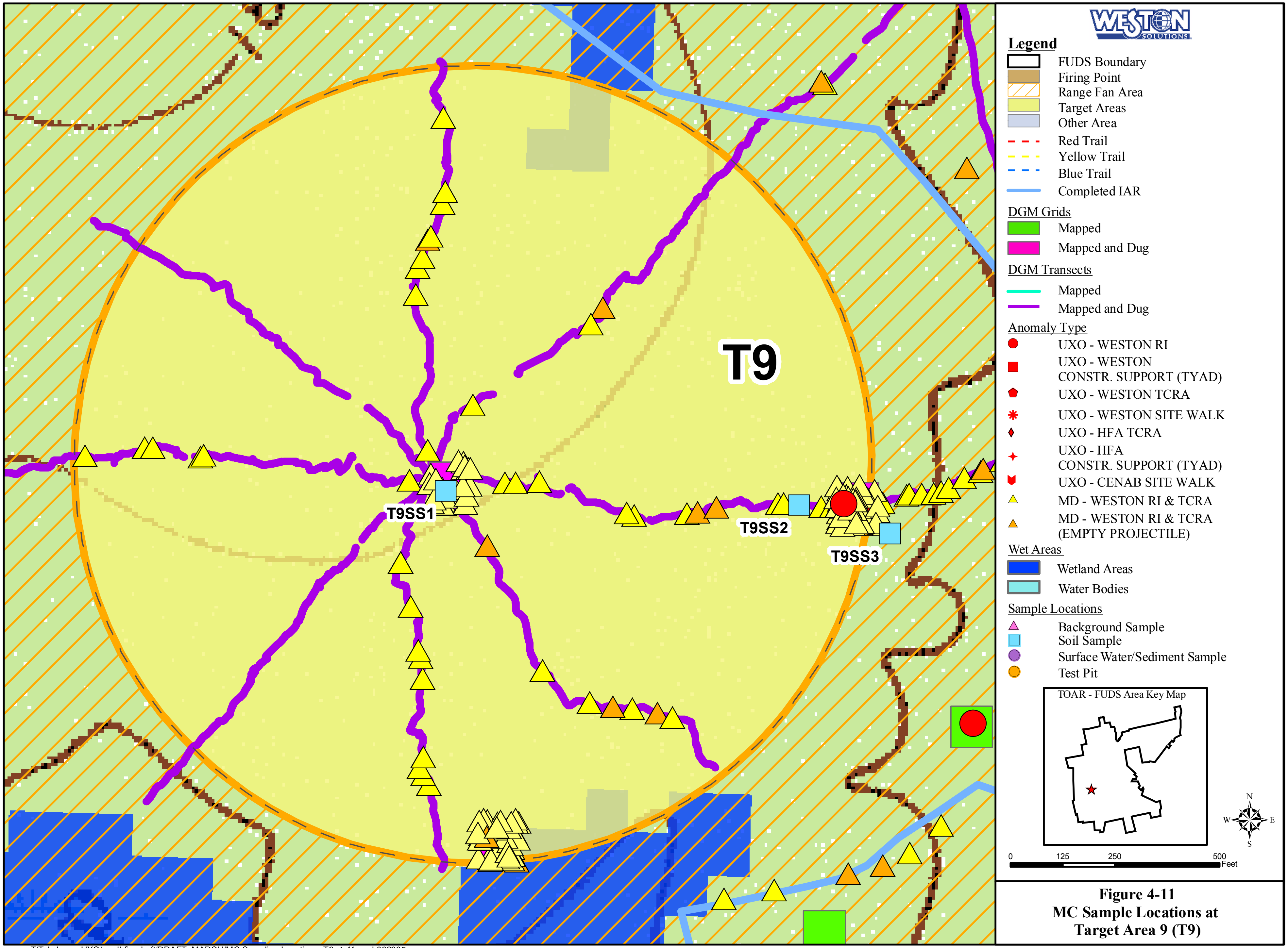


Figure 4-11
MC Sample Locations at Target Area 9 (T9)

T/TobyhannaUXO/mxd/rfis_draft/DRAFT_MARCH/MC Sampling Locations_T9_4-11.mxd 062905

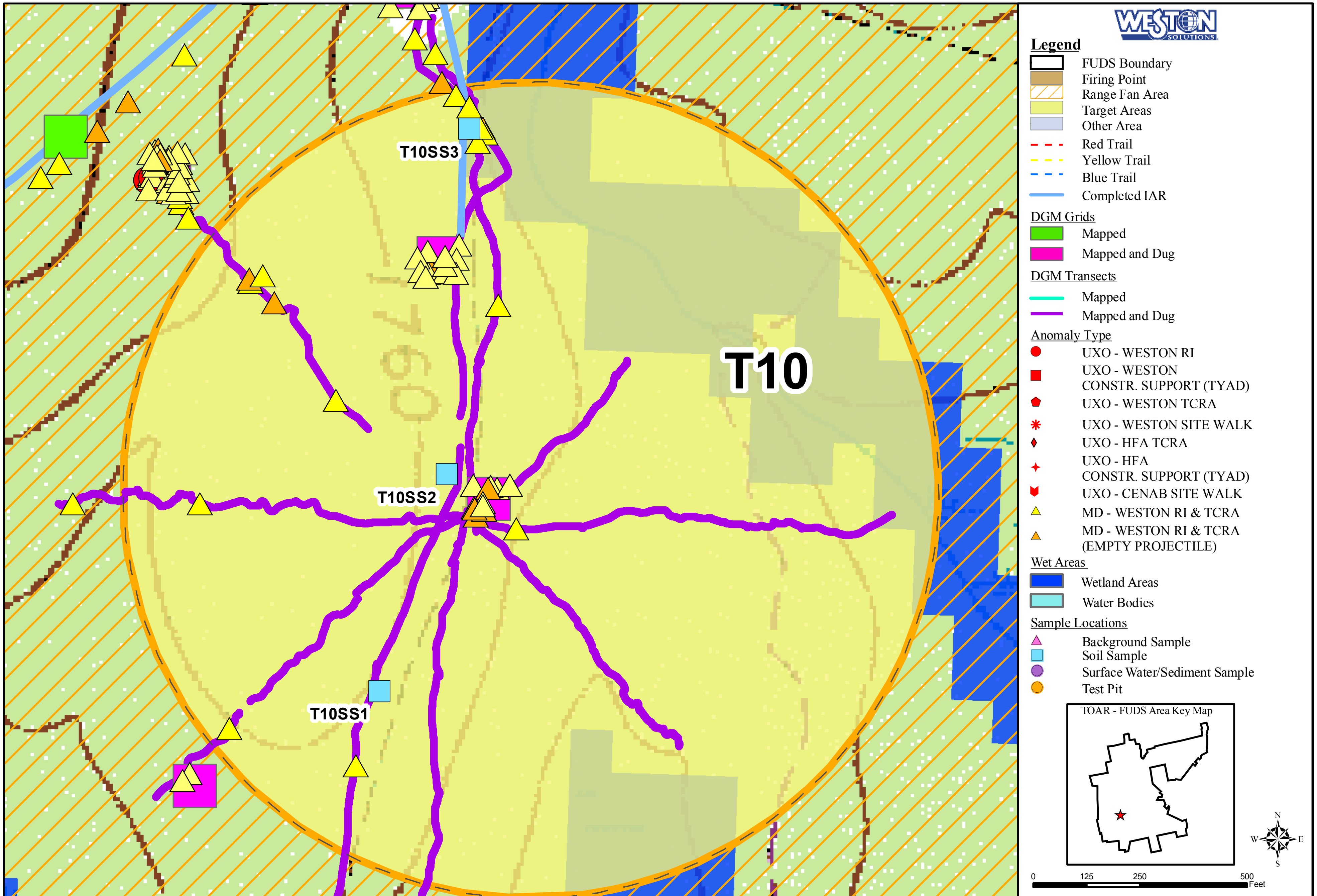


Figure 4-12
MC Sample Locations at Target Area 10 (T10)

T/TobyhannaUXO/mxd/rfis_draft/DRAFT_MARCH/MC Sampling Locations_T10_4-12.mxd 062905

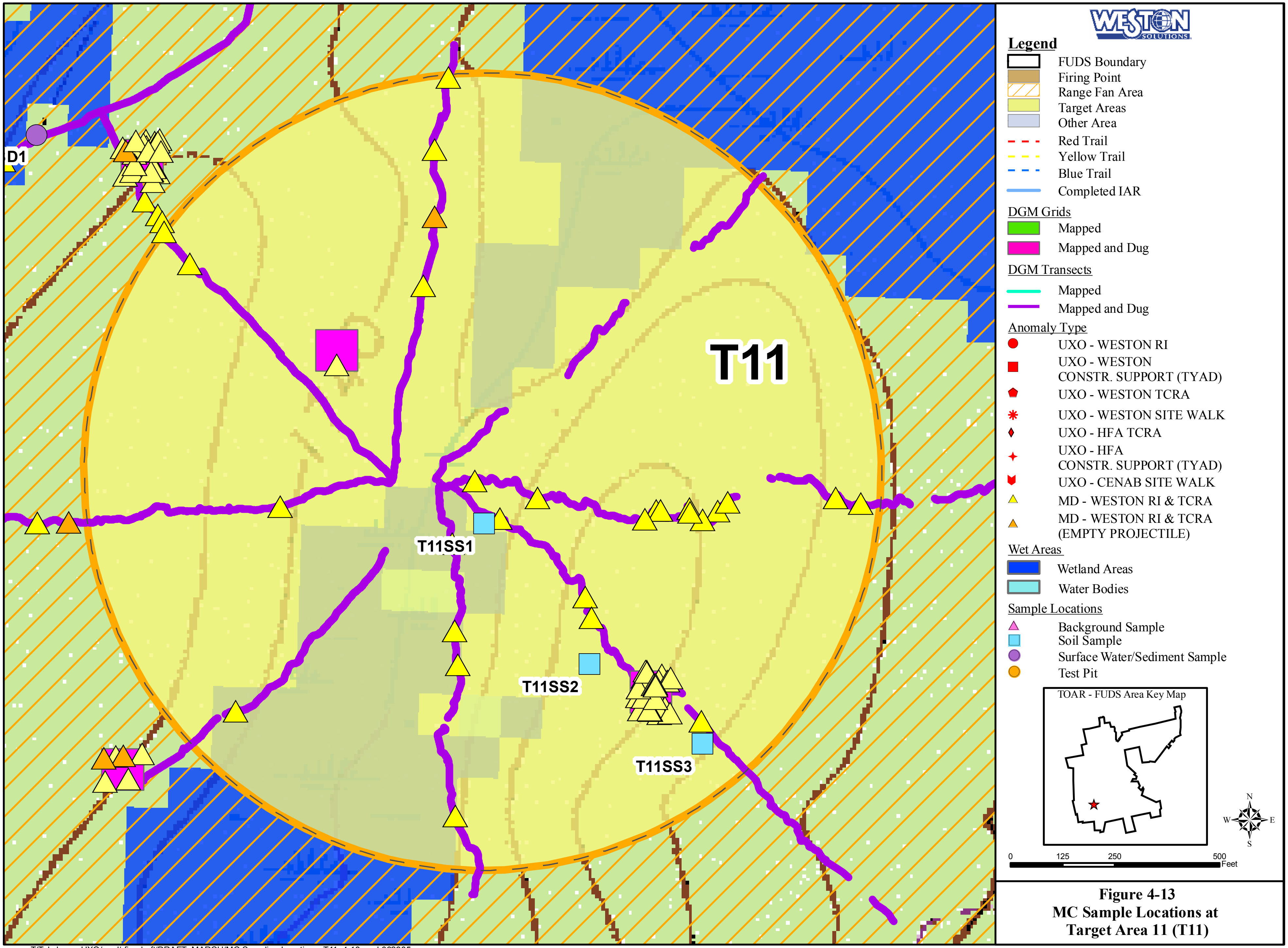


Figure 4-13
MC Sample Locations at Target Area 11 (T11)

T/TobyhannaUXO/mxd/rfis_draft/DRAFT_MARCH/MC Sampling Locations_T11_4-13.mxd 062905

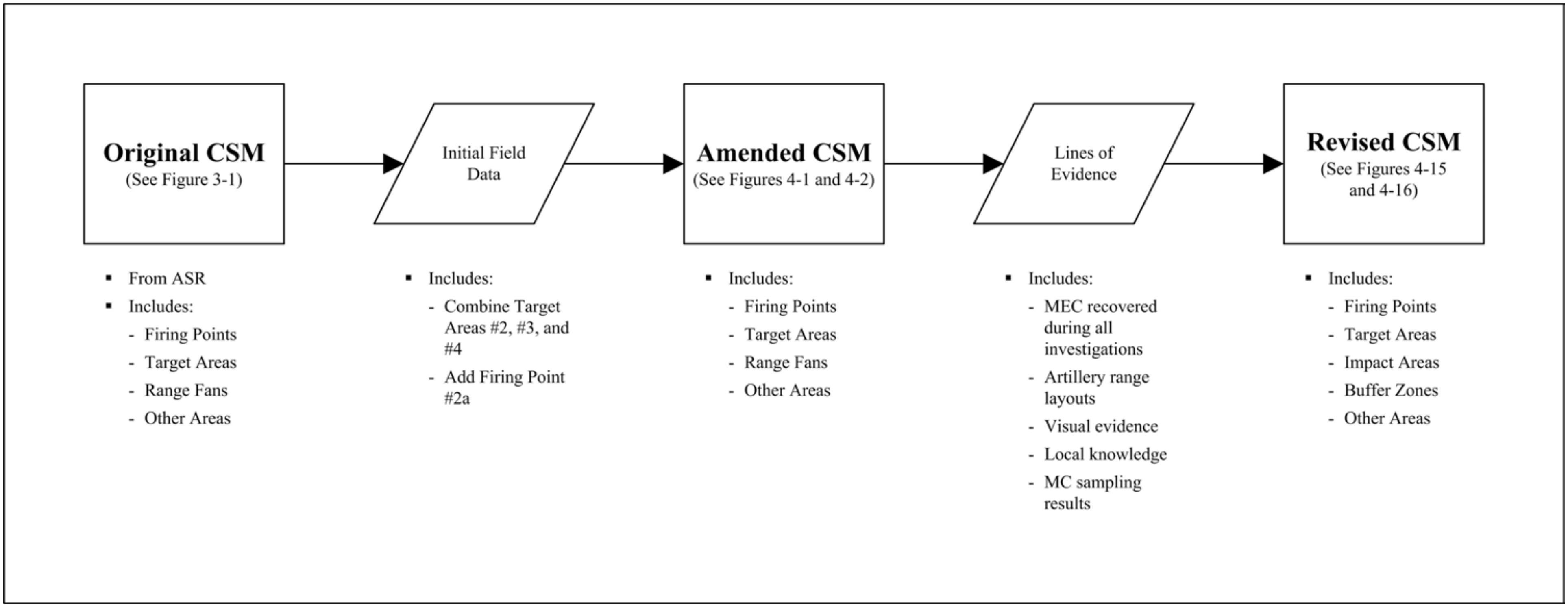


Figure 4-14 Revised CSM Flowchart

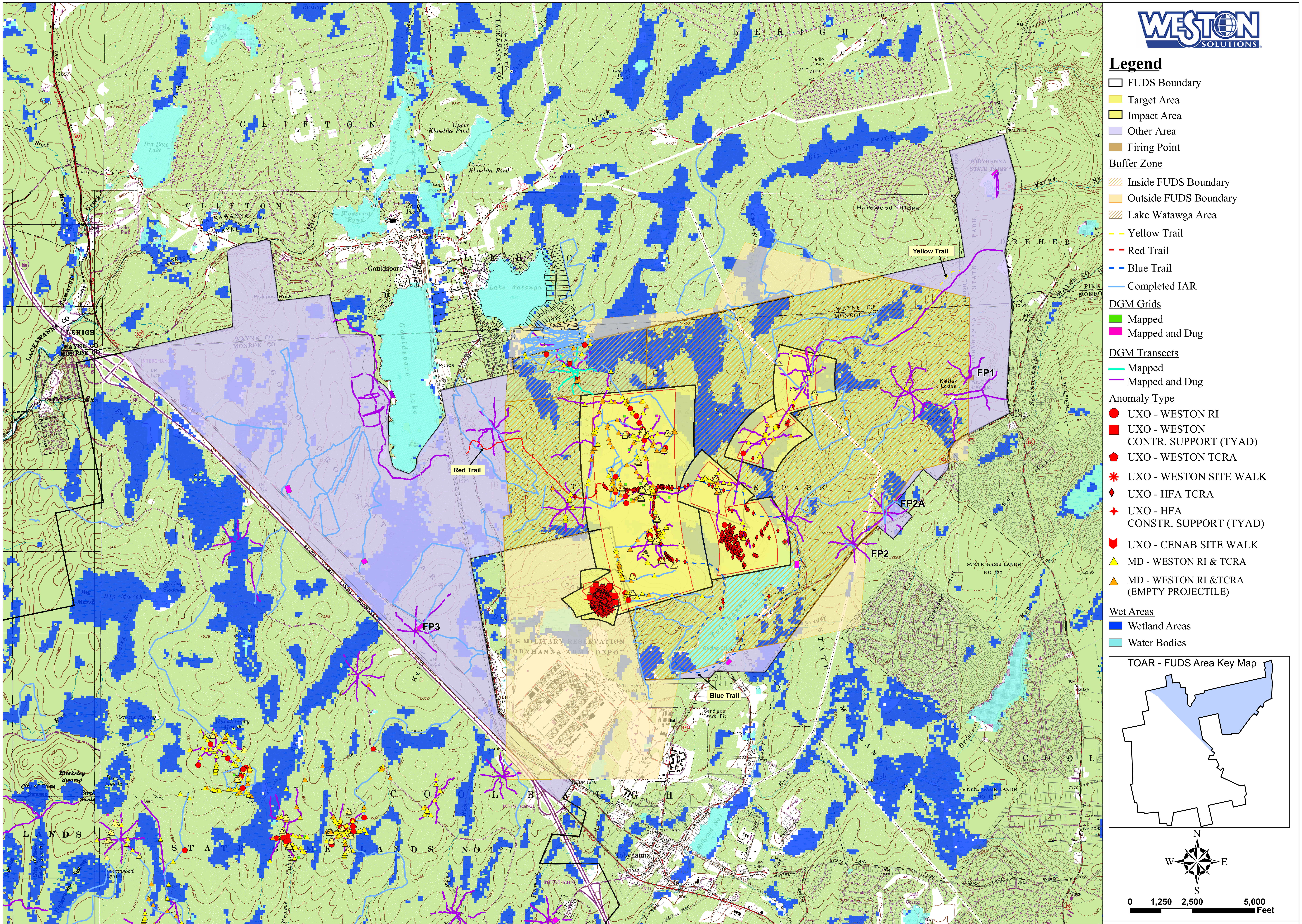
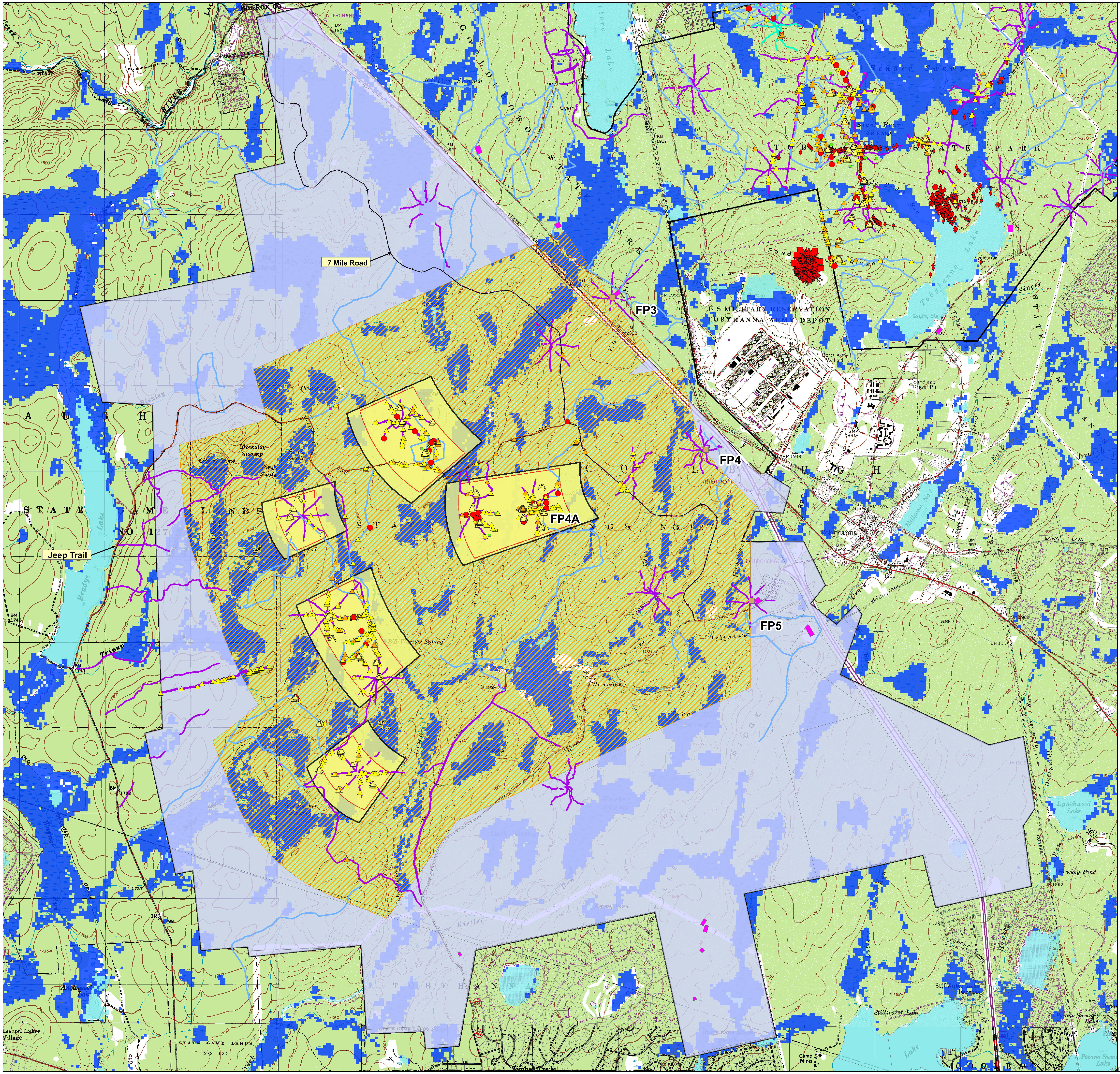


Figure 4-15
Revised CSM
Park

T/TobyhannaUXO/mxd/rfis_draft/march_draft/Revised_Csm_park_4-15.mxd 062205



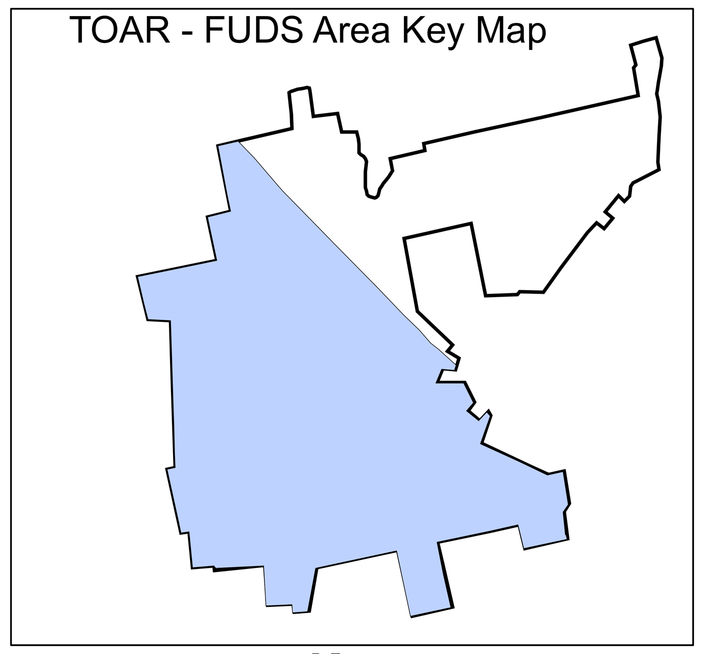


Figure 4-16
Revised CSM
Game

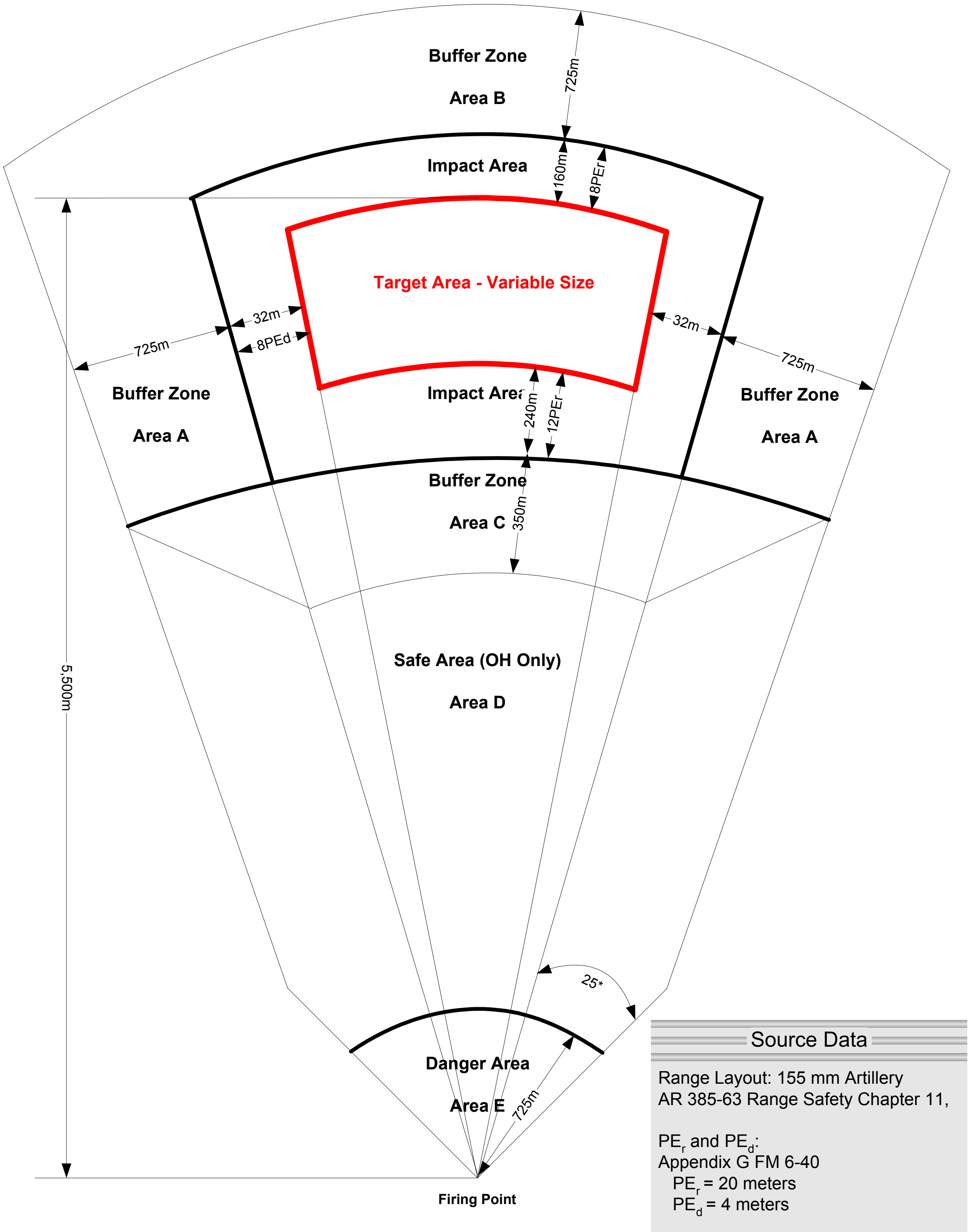


Figure 4-17 Generic 155-mm Artillery Range Layout

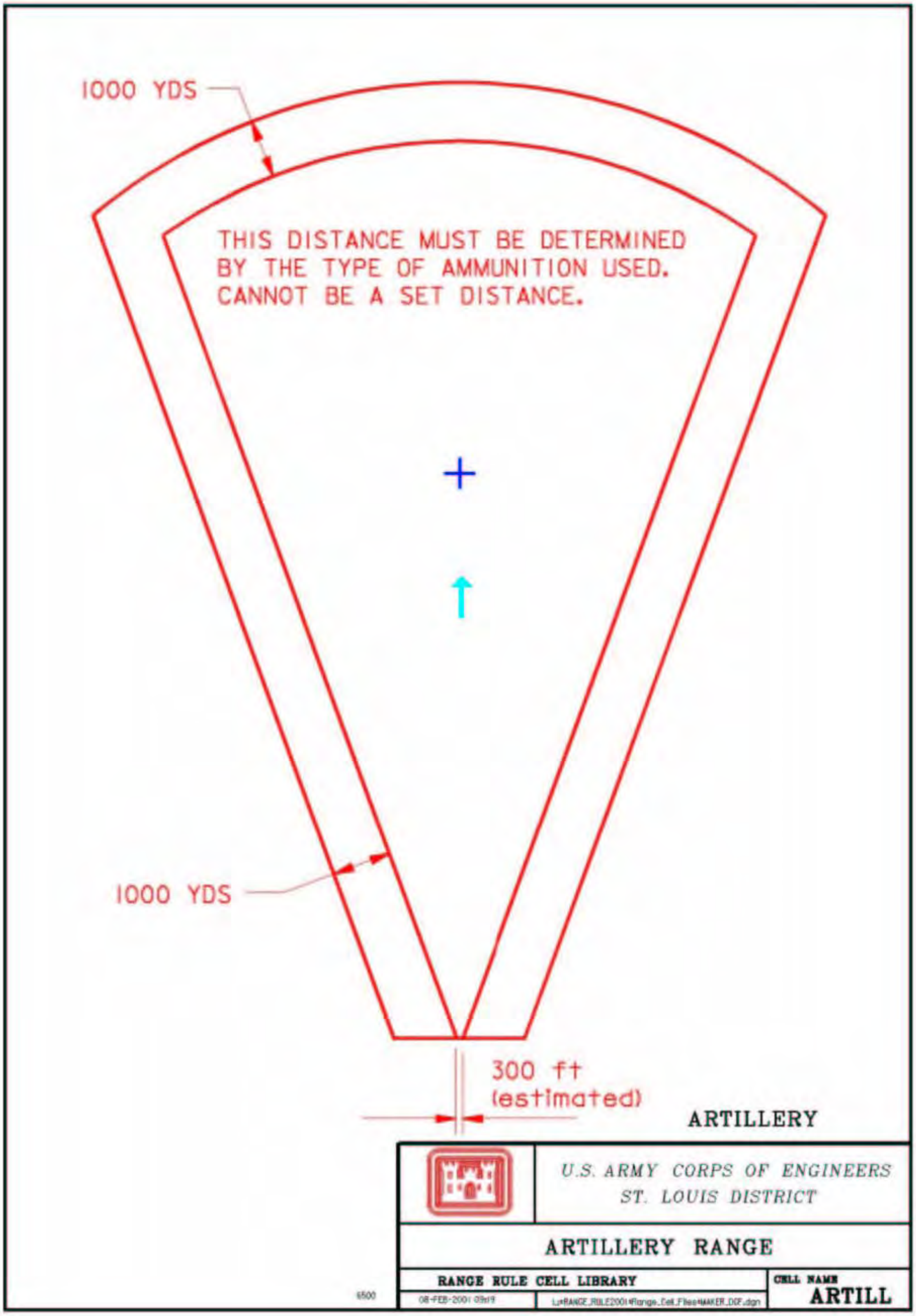


Figure 4-18 Historical Artillery Range Layout

Table 4-1
ASR OE Findings[1]
TOAR-FUDS, Tobyhanna, PA

Area	Name	Size (acres)	ASR OE Finding
A	NE Artillery Range	2,505.50	Confirmed OE Site
B	SW Artillery Range Impact Areas	2,138.85	Confirmed OE Site
C	SW Artillery Range Firing Points	4,762.60	Potential OE Site
D	Machine Gun Range	26.90	Uncontaminated
E	Privately Owned Property	10.00	Uncontaminated
F	Machine Gun Camp	75.05	Uncontaminated
G	Tobyhanna Army Depot	1,343.54	Not FUDS Eligible
H	All Remaining Lands	10,237.41	Uncontaminated
	Total Acreage	21,100	

[1]The term OE was used to remain consistent with the original table in the ASR.
In the ASR, OE includes UXO and MD.

Table 4-2
Live OE (UXO) Items Removed – 1998 HFA TCRA
TOAR-FUDS, Tobyhanna, PA

Area	Approx. Acres Cleared	37mm Projectile	75mm Projectile	155mm Projectile	M1907 Fuze	3 lb Projectile	Totals	UXO Density (UXO/acre)
Campgrounds	150	133	16	0	1	0	**150**	1
Blue Trail	18	20	59	9	0	2	**90**	6.9
Red Trail		3	27	0	0	0	**30**	
Yellow Trail		0	4	0	0	0	**4**	
Beach Area	4.5	0	0	0	0	0	**0**	0
Boat Ramp	4	0	0	0	0	0	**0**	0
Youth Camping	9	0	1	0	0	0	**1**	0.11
Picnic Area	20	0	0	1	0	0	**1**	0.05
Totals	**205.5**	**156**	**107**	**10**	**1**	**2**	**276**	-

Table 4-3
UXO and MD Found - 2004 WESTON TCRA
TOAR-FUDS, Tobyhanna, PA

Grid	Item	UXO/MD	Type	Condition	Depth (in. bgs)	Disposition[1]
7-Mile Road, Magazine and Parking Areas						
Mag Area	75 mm	MD	Shrapnel	Empty	< 6	Held for Demilitarization
Mag Area	75 mm	MD	Fuze Components		< 6	
Mag Area	75 mm	MD	Fuze Components		< 6	
Mag Area	75 mm	MD	Fuze Components		< 6	
Parking Area 7	75 mm	MD	Shrapnel	Empty	4	Held for Demilitarization
85+13.7	155 mm	MD	Frag X2		12	
87+13.8	155 mm	MD	Nose		10	
87+13.8	155 mm	MD	Frag		16	
89+14.1	75 mm	MD	Shrapnel	Empty	12	Held for Demilitarization
89+14.1	75 mm	MD	Frag		18	
107+21.2	75 mm	MD	Shrapnel	Empty	19	Held for Demilitarization
122+05.9	155 mm	UXO	Shrapnel	1/2 Projectile w/Pusher Plate	4	Disposed by Detonation
Trail No. 1						
21+90.5	75 mm	MD	Shrapnel	Empty	< 6	Held for Demilitarization
31+43.6	75 mm	MD	Shrapnel and frag	Empty	< 6	Held for Demilitarization
40+46.5	155 mm	MD	Nose		< 6	
57+77.1	75 mm	MD	Shrapnel	Empty	< 6	Held for Demilitarization
59+09.5	75 mm	MD	Shrapnel	Empty	< 6	Held for Demilitarization
59+09.5	155 mm	MD	Nose		< 6	
62+26.2	75 mm	MD	Frag		< 6	
63+23.3	75 mm	MD	Shrapnel	Empty	< 6	Held for Demilitarization
63+23.3	75 mm	MD	Frag		< 6	
63+23.3	155 mm	MD	Nose		< 6	
65+10.5	155 mm	MD	Nose		< 6	
66+77.2	75 mm	MD	Shrapnel	Empty	< 6	Held for Demilitarization
67+65.5	75 mm	MD	Base Plate		< 6	
71+54.6	75 mm	MD	Frag		< 6	
71+54.6	155 mm	MD	Nose		< 6	
72+10.1	75 mm	MD	Frag		< 6	
72+10.1	75 mm	MD	Shrapnel	Empty	< 6	Held for Demilitarization
73+22.5	155 mm	MD	Nose		< 6	
74+07.4	75 mm	MD	Base Plate		< 6	
76+55.3	75 mm	MD	Shrapnel	Empty	< 6	Held for Demilitarization
77+40.6	155 mm	MD	Nose		< 6	
87+53.6	155 mm	MD	Nose		< 6	

in. bgs = inches below ground surface

[1]Items held for demiliterization were demilitarized and rendered into Munitions Debris. All munitions debris (Scrap) was turned in to the TYAD environmental office for recycling.

Table 4-4
Areas Investigated - 2004 WESTON RI
TOAR-FUDS, Tobyhanna, PA

Area	Approx. Acres	Min No. of Acres To Be Investigated[1]	Acres Mapped But Not Intrusively Investigated[2]		Acres Intrusively Investigated[3]				
			Grids	Transects[4]	Grids	Transects[4]	DGM Total	IAR	Total
Tobyhanna State Park									
Range Fans	4,039	6	0	0.99	2.27	7.91	10.18	102.34	112.52
Target Areas	262	6	2.07	0	5.07	5.68	10.75	28.61	39.36
Other Areas	4,019	6	1	0	3.74	7.04	10.78	52.61	63.39
TOTALS	**8,320**	**18**	**3.07**	**0.99**	**11.08**	**20.63**	**31.71**	**183.56**	**215.27**
Pennsylvania State Gamelands Number 127									
Range Fans	6,135	6	0.92	0	2.99	7.91	10.90	36.91	47.81
Target Areas	393	6	0.92	0	7.13	7.45	14.58	11.48	26.06
Other Areas	6,252	6	0.23	0	5.50	10.62	16.12	38.34	54.46
TOTALS	**12,780**	**18**	**2.07**	**0**	**15.62**	**25.98**	**41.60**	**86.73**	**128.33**

NA = Not applicable

[1]Minimum Acres based on UXO Estimator using risk basis of 0.5 UXO per acre and 95% confidence.

[2]Acres were mapped, but no targets were dug.

[3]Acres were mapped and targets were dug.

[4]Acres investigated along transects were calculated using a width of 3 feet in areas where 37-mm UXO was found, and 5.34 feet in all other areas.

[5]Acres investigated include 12.5 miles of road where 100% mag and dig was used to clear roads under the TCRA.

Table 4-5
Anomalies Investigated - 2004 WESTON RI
TOAR-FUDS, Tobyhanna, PA

Items	Park			Game			
	Target	Range Fans & Firing Points	Other	Target	Range Fans & Firing Points	Other	Totals
MEC							
UXO	34	6	0	22	16	0	**78**
DMM	0	0	0	0	0	0	**0**
MC (reactive)	0	0	0	0	0	0	**0**
Total	34	6	0	22	16	0	**78**
MEC-Related Items							
MD and MC (non-reactive)	1706	177	0	954	515	16	**3368**
Total	1706	177	0	954	515	16	**3368**
Other Anomalies							
Non-MEC	106	798	454	214	357	655	**2584**
False Positives	137	85	27	110	22	11	**392**
Total	243	883	481	324	379	666	**2976**
Total Anomalies Investigated	**1983**	**1066**	**481**	**1300**	**910**	**682**	**6422**

Table 4-6
UXO Found in Target Areas - 2004 WESTON RI
TOAR-FUDS, Tobyhanna, PA

Item ID	Size	Ordnance Description	Ammuniton Type	Depth (in. bgs)	Final Disposition
Tobyhanna State Park					
IR1-IAR1-42904-002-1	75	Projectile	Shrapnel	0	Disposed by detonation
IR1-IAR1-42904-005-1	75	Projectile	Shrapnel	0	Disposed by detonation
IR27-EECA1-62404-0027-1	75	Projectile	Shrapnel	6	Disposed by detonation
IR27-EECA1-62404-0034-1	155	Projectile	Shrapnel	6	Disposed by detonation
IR6-IAR1-51004-0041-1	155	Projectile	Shrapnel	0	Disposed by detonation
T2G6-142-1	75	Projectile	Shrapnel	3	Disposed by detonation
T2T1-EECA2-001-1	75	Projectile	Shrapnel	0	Disposed by detonation
T3G5-169-1	75	Projectile	Shrapnel	0	Disposed by detonation
T3G6-46-1	75	Projectile	Shrapnel	0	Disposed by detonation
T4G2-121-1	37	Projectile	High explosive	6	Blown in place
T4G5-186-1	75	Projectile	Shrapnel	3	Disposed by detonation
T4G5-274-2	75	Projectile	Shrapnel	10	Disposed by detonation
T4G5-390-1	75	Projectile	Shrapnel	2	Disposed by detonation
T4G5-405-1	75	Projectile	Shrapnel	2	Disposed by detonation
T4G5-534-1	75	Projectile	Shrapnel	3	Disposed by detonation
T4G8-358-1	75	Projectile	Shrapnel	2	Disposed by detonation
IR6-IAR1-51004-0045-1	155	Projectile	High explosive	0	Disposed by detonation
IR7-IAR1-51104-001-1	155	Projectile	High explosive	0	Disposed by detonation
RA17G1-130-1	37	Projectile	High explosive	1	Blown in place
T2G1-IAR1-001-1	155	Projectile	High explosive	0	Blown in place
T2G1-IAR2-001-1	155	Projectile	High explosive	0	Disposed by detonation
T2G4-IAR1-001-1	155	Projectile	High explosive	0	Blown in place
T2G4-IAR2-001-1	155	Projectile	High explosive	0	Disposed by detonation
T2G6-379-1	75	Projectile	High explosive	0	Disposed by detonation
T2T1-94-1	155	Projectile	High explosive	14	Disposed by detonation
T2T2-IAR1-001-1	155	Projectile	High explosive	0	Blown in place
T3G5-150-1	75	Projectile	High explosive	0	Disposed by detonation
T3G5-292-1	75	Projectile	High explosive	1	Disposed by detonation
T3T1-EECA1-001-1	155	Projectile	High explosive	0	Disposed by detonation
T4G5-415-1	75	Projectile	High explosive	4	Blown in place
T4G5-471-1	3-lb	Projectile	High explosive	6	Disposed by detonation
T4G5-577-1	75	Projectile	High explosive	4	Disposed by detonation
T4G5-605-1	37	Projectile	High explosive	3	Blown in place
T4G8-324-1	155	Projectile	Shrapnel	0	Blown in place
Pennsylvania State Gameland Number 127					
IR10-IAR1-52604-043-1	155	Projectile	Shrapnel	0	Disposed by detonation
IR10-IAR1-52604-045-1	75	Projectile	Shrapnel	0	Disposed by detonation
RA11T6-23-1	75	Projectile	Shrapnel	1	Disposed by detonation
RA11T8-3-1	75	Projectile	Shrapnel	6	Disposed by detonation
T6T4-3-1	155	Projectile	Shrapnel	12	Disposed by detonation
T8G4-140-1	75	Projectile	Shrapnel	4	Disposed by detonation
T8G4-187-1	75	Projectile	High explosive	2	Disposed by detonation
T8T2-12-2	155	Projectile	Shrapnel	5	Disposed by detonation
IR10-IAR1-52604-032-1	75	Projectile	High explosive	0	Disposed by detonation
RA11T5-IAR1-001-1	155	Projectile	High explosive	0	Blown in place
RA11T6-IAR1-001-1	155	Projectile	High explosive	0	Blown in place
RA11T7-IAR1-001-1	155	Projectile	High explosive	0	Disposed by detonation
T6T4-6-1	81	Mortar projectile	Practice	0	Disposed by detonation
T8G1-IAR1-001-1	75	Projectile	Shrapnel	0	Disposed by detonation
T8G1-IAR1-001-2	75	Projectile	Shrapnel	0	Disposed by detonation
T8G2-IAR1-001-1	75	Projectile	Shrapnel	0	Disposed by detonation
T8G4-147-1	155	Projectile	High explosive	2	Blown in place
T8G5-EECA2-001-1	155	Not available	High explosive	0	Disposed by detonation
T8G5-IAR2-001-1	155	Not available	High explosive	0	Disposed by detonation
T8T2-15-2	75	Projectile	High explosive	2	Disposed by detonation
T8T2-IAR1-001-1	155	Projectile	High explosive	0	Disposed by detonation
T9G2-120-1	75	Projectile	High explosive	12	Disposed by detonation

Table 4-7
UXO Distribution by Type – 2004 WESTON RI
TOAR-FUDS, Tobyhanna, PA

UXO Source Area Depth		UXO Distribution by Type 37mm 5%	75-81mm 51%	155mm 44%	Totals
FP - Game	**Totals**	**0**	**0**	**0**	**0**
FP - Park	**Totals**	**0**	**0**	**0**	**0**
TA - Game	**Totals**	**0**	**12**	**10**	**22**
0-6 inch		0	11	9	20
6-12 inch		0	1	1	2
>12 inch		0	0	0	0
TA - Park	**Totals**	**3**	**18**	**13**	**34**
0-6 inch		3	17	12	32
6-12 inch		0	1	0	1
>12 inch		0	0	1	1
RF - Game	**Totals**	**0**	**8**	**8**	**16**
0-6 inch		0	4	5	9
6-12 inch		0	3	1	4
>12 inch		0	1	2	3
RF - Park	**Totals**	**1**	**2**	**3**	**6**
0-6 inch		1	2	3	6
6-12 inch		0	0	0	0
>12 inch		0	0	0	0
Other - Game	**Totals**	**0**	**0**	**0**	**0**
Other - Park	**Totals**	**0**	**0**	**0**	**0**

Table 4-8
UXO Distribution by Depth – 2004 WESTON RI
TOAR-FUDS, Tobyhanna, PA

UXO Source Area UXO Type		UXO Distribution by Depth 0-6 inch 86%	6-12 inch 9%	>12 inch 5%	Totals
FP - Game	**Totals**	**0**	**0**	**0**	**0**
FP - Park	**Totals**	**0**	**0**	**0**	**0**
TA - Game	**Totals**	**20**	**2**	**0**	**22**
37mm		0	0	0	0
75-81mm		11	1	0	12
155mm		9	1	0	10
TA - Park	**Totals**	**32**	**1**	**1**	**34**
37mm		3	0	0	3
75-81mm		17	1	0	18
155mm		12	0	1	13
RF - Game	**Totals**	**9**	**4**	**3**	**16**
37mm		0	0	0	0
75-81mm		4	3	1	8
155mm		5	1	2	8
RF - Park	**Totals**	**6**	**0**	**0**	**6**
37mm		1	0	0	1
75-81mm		2	0	0	2
155mm		3	0	0	3
Other - Game	**Totals**	**0**	**0**	**0**	**0**
Other - Park	**Totals**	**0**	**0**	**0**	**0**

Table 4-9
UXO Found in Range Safety Fans - 2004 WESTON RI
TOAR-FUDS, Tobyhanna, PA

Item ID	Size (mm)	Ordnance Description	Ammuniton Type	Depth (in. bgs)	Final Disposition
Tobyhanna State Park					
IR8-IAR1-52504-027-1	155	Projectile	Shrapnel	0	Disposed by detonation
RA14G1-69-1	155	Projectile	Shrapnel	0	Disposed by detonation
RA14G1-99-1	75	Projectile	Shrapnel	4	Disposed by detonation
RA1G6-EECA3-001-1	155	Frag	High explosive	2	Disposed by detonation
IR8-IAR1-52504-016-1	75	Projectile	High explosive	0	Disposed by detonation
RA14T1-IAR1-001-1	37	Projectile	High explosive	0	Blown in Place
Pennsylvania State Gameland Number 127					
IR43-EECA3-81704-0027-1	75	Projectile	Shrapnel	9	Disposed by detonation
IR45G2-30-1	155	Fuze	Shrapnel	3	Disposed by detonation
IR47-EECA3-9704-009-1	155	Projectile	Shrapnel	24	Disposed by detonation
IR50-EECA2-9604-0012-1	75	Projectile	Shrapnel	2	Disposed by detonation
IR50-EECA2-9604-0022-1	155	Projectile	Shrapnel	7	Disposed by detonation
IR52-EECA3-9704-0018-1	155	Projectile	Shrapnel	18	Disposed by detonation
IR52-EECA3-9704-008-1	155	Projectile	Shrapnel	0	Disposed by detonation
T10G2-63-1	75	Projectile	Shrapnel	2	Disposed by detonation
T6G7-32-1	75	Projectile	Shrapnel	0	Disposed by detonation
T6G7-91-1	75	Projectile	Shrapnel	11	Disposed by detonation
T6G7-92-1	75	Projectile	Shrapnel	11	Disposed by detonation
T6T2-27-1	75	Projectile	Shrapnel	1	Disposed by detonation
T9G2-52-1	75	Projectile	Shrapnel	24	Disposed by detonation
IR45G2-48-1	155	Projectile	High explosive	0	Disposed by detonation
T10G2-54-1	155	Projectile	High explosive	6	Disposed by detonation
T9G3-IAR1-001-1	155	Projectile	Shrapnel	0	Disposed by detonation

Table 4-10
UXO Density - 2004 WESTON RI
TOAR-FUDS, Tobyhanna, PA

Area	Total Approx. Acres	Total Acres Investigated	No. of UXO Items Found	UXO Density (items/acre)
Tobyhanna State Park - DGM				
Range Fans	4,039	10.18	4	0.393
Target Areas	262	10.75	27	2.512
Other Areas	4,019	10.78	0	0.000
Tobyhanna State Park - IAR				
Range Fans	4,039	102.34	2	0.020
Target Areas	262	28.61	7	0.245
Other Areas	4,019	52.61	0	0.000
Pennsylvania State Gamelands Number 127 - DGM				
Range Fans	6,135	10.90	10	0.917
Target Areas	393	14.58	19	1.303
Other Areas	6,252	16.12	0	0.000
Pennsylvania State Gamelands Number 127 - IAR				
Range Fans	6,135	36.91	6	0.163
Target Areas	393	11.48	3	0.261
Other Areas	6,252	38.34	0	0.000

Table 4-11
Background Surface Soil Samples - 2004 WESTON RI
Metals Results
TOAR-FUDS, Tobyhanna, PA

	Field Sample ID	TOAR-GLBG-4285-005	TOAR-GLBG-4285-006	TOAR-GLBG-4285-007	TOAR-GLBG-4285-008	TOAR-SPBG-4285-001	TOAR-SPBG-4285-002	TOAR-SPBG-4285-003	TOAR-SPBG-4285-004	TOAR-SPBG-4285-101
	Sample Date	10/11/2004	10/11/2004	10/11/2004	10/11/2004	10/11/2004	10/11/2004	10/11/2004	10/11/2004	10/11/2004
	Location ID	GLBG-005	GLBG-006	GLBG-007	GLBG-008	SPBG-001	SPBG-002	SPBG-003	SPBG-004	SPBG-101
	Depth (in)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Parameter	**Units**									
Lead	mg/kg	63 j	83.8 j	40.7 j	25.4 j	15.2 j	17.7 j	67.8 j	115 j	37.8 j
Nickel	mg/kg	4.5 bj	3.5 bj	1.9 bj	1.3 bj	2.9 bj	2.3 bj	2.6 bj	3.2 bj	6.2 bj
Silver	mg/kg	0.55 bj	0.47 bj	0.3 bj	0.35 bj	1.1 j	0.76 j	0.7 bj	0.73 bj	1.1 j
Thallium	mg/kg	1.5 u	1.5 u	1.3 u	1.7 u	1.4 u	1.3 u	1.6 u	1.8 u	1.9 u
Antimony	mg/kg	0.99 b	1.5 u	0.41 b	1.7 u	1.4 u	1.3 u	0.6 b	0.58 b	1.9 u
Arsenic	mg/kg	8.8	4.7	2.8	3.4	2.5	3.4	7.7	4.1	6.9
Beryllium	mg/kg	0.61 u	0.59 u	0.51 u	0.69 u	0.55 u	0.52 u	0.64 u	0.72 u	0.75 u
Cadmium	mg/kg	0.86	0.83	0.73	0.41 b	0.52 b	0.31 b	0.77 b	0.49 b	1.1
Chromium	mg/kg	7.3 j	6.5 j	3.1 j	3.3 j	4.7 j	4 j	4.9 j	3.8 j	9 j
Copper	mg/kg	12.6 j	10.5 j	7.3 j	5.2 j	7.8 j	4.9 j	11.4 j	10.5 j	8.6 j
Zinc	mg/kg	58.2	32.7	22.2	16.2	30.9	14.1	22.4	27.2	61.8
Selenium	mg/kg	1.9	1.1	0.86	1.1	1.2	0.57 b	1.7	1.5	0.84 b
Mercury	mg/kg	0.15	0.14	0.074	0.081	0.16	0.1	0.15	0.14	0.21

j = Method blank contamination. The associated method blank contains the target analyte at a reportable level.
u = Not detected. Reporting limit shown.
b = Estimated result. Result is less than the reporting limit.

Table 4-12
Surface Soil Samples - 2004 WESTON RI
Metals Results
TOAR-FUDS, Tobyhanna, PA

	Field Sample ID	F2-SS-4257-002	F2A-SS-4257-001	F2A-SS-4257-002	F2-SS-4257-001	F3-SS-4257-001	F3-SS-4257-002	F4-SS-4258-001	F4-SS-4258-002	F4-SS-4258-102
	Sample Date	9/13/2004	9/13/2004	9/13/2004	9/13/2004	9/13/2004	9/13/2004	9/14/2004	9/14/2004	9/14/2004
	Location ID	F2-33-002	F2A-SS-001	F2A-SS-002	F2-SS-001	F3-SS-001	F3-SS-002	F4-SS-001	F4-SS-002	F4-SS-102
	Depth (in)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Parameter	Units									
Lead	mg/kg	52.2	129	131	127	75.9	66.1	45.5	84.3	63.8
Nickel	mg/kg	3.3 b	4 b	3.4 b	13.5 b	3.2 b	2.3 b	3.5 b	4.3 b	3.7 b
Silver	mg/kg	0.064 b	0.24 b	0.74 u	0.85 b	0.36 b	0.21 b	0.26 b	0.14 b	0.099 b
Thallium	mg/kg	1.4 u	3.1 u	0.7 b	3.6 u	2.1 u	1.6 u	2.4 u	2.6 u	2.2 u
Antimony	mg/kg	0.57 b	1.2 b	0.81 b	3 b	0.93 b	0.69 b	1.3 b	1.6 b	1.2 b
Arsenic	mg/kg	5.4	2.5 b	6	10.1	2 b	2.5	5.2	6.5	4.9
Beryllium	mg/kg	0.35 bj	0.68 bj	0.39 bj	1.7 j	0.44 bj	0.36 bj	0.79 bj	0.77 bj	0.66 bj
Cadmium	mg/kg	0.68 b	0.49 b	0.74 u	1.5 b	0.57 b	0.34 b	0.31 b	0.32 b	0.28 b
Chromium	mg/kg	3.7	2.5	7.8	11.6	2.6	2.2	4.6	6.5	5.1
Copper	mg/kg	10.7	23.8	167	41.3 j	10.6	10	10.9	14	11.1
Zinc	mg/kg	30.9 j	70.9 j	72.7 j	154	41.7 j	28 j	26.3 j	42.9 j	36.2 j
Selenium	mg/kg	0.94	1.1 b	0.47 b	4.7	1.5	0.91	1.9	1.7	1.4
Mercury	mg/kg	0.12	0.2	0.15	0.47	0.21	0.13	0.18	0.2	0.17

	Field Sample ID	F5-SS-4257-001	F5-SS-4257-002	T10-SS-4258-001	T10-SS-4258-002	T10-SS-4258-003	T11-SS-4259-001	T1-SS-4257-001	T11-SS-4259-002	T11-SS-4259-003
	Sample Date	9/13/2004	9/13/2004	9/14/2004	9/14/2004	9/14/2004	9/15/2004	9/13/2004	9/15/2004	9/15/2004
	Location ID	F5-SS-001	F5-SS-002	T10-SS-001	T10-SS-002	T10-SS-003	T11-SD-001	T11-SS-001	T11-SS-002	T11-SS-003
	Depth (in)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Parameter	Units									
Lead	mg/kg	28.5	46.7	50.3	23.8	67.7	39	65.1	63.4	23.4
Nickel	mg/kg	2 b	1.9 b	2.4 b	4.2 b	2.5 b	1.6 b	2.7 b	10.2	1 b
Silver	mg/kg	0.21 b	0.098 b	0.14 b	0.039 b	0.93 u	0.14 b	0.14 b	0.087 b	0.64 u
Thallium	mg/kg	2 u	1.9 u	0.91 b	0.59 b	1.9 u	0.8 b	1.8 u	1.3 u	1.3 u
Antimony	mg/kg	0.89 b	1.9 u	0.61 b	0.45 b	0.82 b	0.63 b	0.68 b	0.65 b	1.3 u
Arsenic	mg/kg	3.9	2.4	5.6	3.7	3.6	4.5	3.8	5.7	4.2
Beryllium	mg/kg	0.54 bj	0.42 bj	0.34 bj	0.47 bj	0.72 bj	0.35 bj	0.43 bj	0.42 bj	0.31 bj
Cadmium	mg/kg	0.99 u	0.39 b	0.65 u	0.63 u	0.15 b	0.72 u	0.45 b	0.67 u	0.64 u
Chromium	mg/kg	3.9	2	5.4	6	3.9	4.7	2.9	6.8	3.4
Copper	mg/kg	7.3	6	8.4 j	9 j	8.1 j	7.4 j	12.6	10.2 j	4.4 j
Zinc	mg/kg	18.1 j	34 j	18.2	23.4	18	18.2	28.4 j	25	11
Selenium	mg/kg	1.2	0.67 b	1	0.38 b	0.9 b	0.65 b	1.3	0.69	0.4 b
Mercury	mg/kg	0.18	0.085	0.1	0.062	0.1	0.1	0.12	0.097	0.051

j = Method blank contamination. The associated method blank contains the target analyte at a reportable level.
u = Not detected. Reporting limit shown.
b = Estimated result. Result is less than the reporting limit.

Table 4-12 (continued)
Surface Soil Samples - 2004 WESTON RI
Metals Results
TOAR-FUDS, Tobyhanna, PA

	Field Sample ID	T1-SS-4257-002	T1-SS-4257-003	T2-SS-4251-001	T2-SS-4251-002	T2-SS-4251-003	T3-SS-4251-001	T3-SS-4251-002	T3-SS-4251-003	T3-SS-4251-103
	Sample Date	9/13/2004	9/13/2004	9/7/2004	9/7/2004	9/7/2004	9/7/2004	9/7/2004	9/7/2004	9/7/2004
	Location ID	T1-SS-002	T1-SS-003	T2-SS-001	T2-SS-002	T2-SS-003	T3-SS-001	T3-SS-002	T3-SS-003	T3-SS-103
	Depth (in)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Parameter	Units									
Lead	mg/kg	48	67.1	112	161	55.2	81.2	198	84	93.8
Nickel	mg/kg	2.3 b	2.5 b	2.1 b	4.7 b	6.7	2.4 b	4.4 b	3.5 b	3.5 b
Silver	mg/kg	0.094 b	0.11 b	0.68 u	0.64 u	0.63 u	0.047 b	0.64 u	0.056 b	0.63 u
Thallium	mg/kg	1.7 u	0.88 b	1.4 u	1.3 u	1.3 u	1.4 u	1.3 u	1.2 u	1.3 u
Antimony	mg/kg	0.67 b	0.77 b	1.4 u	1.3 u	1.3 u	1.4 u	1.8	0.52 b	0.79 b
Arsenic	mg/kg	5.4	22.7	3.2	5.2	5.5	6.2	6.7	7.2	7.3
Beryllium	mg/kg	0.34 bj	0.41 bj	0.54 u	0.51 u	0.055 b	0.54 u	0.071 b	0.5 u	0.5 u
Cadmium	mg/kg	0.83 u	0.81 u	0.27 b	0.44 b	0.42 b	0.32 b	0.47 b	0.38 b	0.4 b
Chromium	mg/kg	4.4	3.9	5.4	7.4	6	4.7	7.3	6	6.9
Copper	mg/kg	14.7 e	16.8	11.1 j	12 j	10.4 j	11.8 j	14.7 j	16.8 j	11.5 j
Zinc	mg/kg	17.1 j	18.6 j	13.3	20	21.7	20.7	25.7	18	18.3
Selenium	mg/kg	0.8 b	1.4	0.58 b	1	0.76	1.1	0.93	0.64	0.94
Mercury	mg/kg	0.091	0.11	0.057	0.11	0.1	0.17	0.1	0.083	0.093

	Field Sample ID	T4-SS-4251-001	T4-SS-4251-002	T4-SS-4251-003	T6-SS-4259-001	T6-SS-4259-002	T6-SS-4259-003	T6-SS-4259-102	T7-SS-4258-001	T7-SS-4258-003
	Sample Date	9/7/2004	9/7/2004	9/7/2004	9/15/2004	9/15/2004	9/15/2004	9/15/2004	9/14/2004	9/14/2004
	Location ID	T4-SS-001	T4-SS-002	T4-SS-003	T6-SS-001	T6-SS-002	T6-SS-003	T6-SS-102	T7-SS-001	T7-SS-003
	Depth (in)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Parameter	Units									
Lead	mg/kg	611	247	255	375	104	187	108	39.3	28.3
Nickel	mg/kg	2.8 b	2.8 b	3.6 b	7.6	4.3 b	2.4 b	5 b	4.7 b	1.6 b
Silver	mg/kg	0.67 u	0.5 u	0.054 b	1.2	0.14 b	0.11 b	0.083 b	0.084 b	0.66 u
Thallium	mg/kg	1.3 u	1 u	1.4 u	1.4 b	1.4 u	1.4 u	1.4 u	1.1 b	1.3 u
Antimony	mg/kg	10	0.81 b	5.7	1.5 b	0.8 b	0.98 b	0.72 b	0.86 b	0.56 b
Arsenic	mg/kg	9.5	8.6	19.9	22.1	21.3	6.7	20.3	6.7	4.1
Beryllium	mg/kg	0.54 u	0.4 u	0.56 u	0.99 j	0.41 bj	0.36 bj	0.41 bj	0.37 bj	0.3 bj
Cadmium	mg/kg	0.4 b	0.27 b	0.6 b	0.79 b	0.71 u	0.24 b	0.72 u	0.7 u	0.66 u
Chromium	mg/kg	7.1	5	7.2	9.3	8.6	3.1	10.1	10	4.9
Copper	mg/kg	18.8 j	12.7 j	42.8 j	33 j	11 j	10.8 j	11.2 j	7.1 j	3.7 j
Zinc	mg/kg	19	22.1	84	107	25.6	26.6	27.2	23.3	10.9
Selenium	mg/kg	1.3	0.39 b	1.2	2.3	1.2	0.95	1.3	0.93	0.95
Mercury	mg/kg	0.18	0.082	0.23	0.15	0.14	0.096	0.15	0.16	0.08

j = Method blank contamination. The associated method blank contains the target analyte at a reportable level.
u = Not detected. Reporting limit shown.
b = Estimated result. Result is less than the reporting limit.

Table 4-12 (continued)
Surface Soil Samples - 2004 WESTON RI
Metals Results
TOAR-FUDS, Tobyhanna, PA

	Field Sample ID	T7-SS-4258-103	T8-SS-4258-001	T8-SS-4258-002	T8-SS-4258-003	T9-SS-4258-001	T9-SS-4258-002	T9-SS-4258-003	T7-SS-4258-002
	Sample Date	9/14/2004	9/14/2004	9/14/2004	9/14/2004	9/14/2004	9/14/2004	9/14/2004	9/14/2004
	Location ID	T7-SS-103	T8-SS-001	T8-SS-003	T8-SS-003	T9-SS-001	T9-SS-002	T9-SS-003	TOSR-T7-SS-002
	Depth (in)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Parameter	**Units**								
Lead	mg/kg	28.2	56	37.3	197	45.6	66.3	33.1	87.5
Nickel	mg/kg	2.3 b	4.1 b	2.5 b	2.3 b	4.3 b	1.9 b	2.8 b	4.2 b
Silver	mg/kg	0.7 u	0.67 u	0.077 b	0.21 b	0.38 b	0.12 b	0.64 u	0.18 b
Thallium	mg/kg	0.83 b	1.3 u	1.7 u	1.7 u	1.5 u	1.8 u	0.64 b	1.6 u
Antimony	mg/kg	0.72 b	1 b	0.98 b	1.9	0.78 b	7.6	0.75 b	0.74 b
Arsenic	mg/kg	4.4	6.1	7.8	3.9	6.9	5.8	5.3	6.4
Beryllium	mg/kg	0.32 bj	0.4 bj	0.41 bj	0.39 bj	0.47 bj	0.37 bj	0.31 bj	0.35 bj
Cadmium	mg/kg	0.7 u	0.67 u	0.85 u	0.25 b	0.27 b	0.9 u	0.64 u	0.18 b
Chromium	mg/kg	5.5	11.4	9.2	3.6	8.2	5	8	6.5
Copper	mg/kg	4.2 j	31.3	4.2 b	9.7	10.2 j	7.7 j	4.4 j	10.1 j
Zinc	mg/kg	12	20.2 j	17.4 j	26.7 j	38.1	27.7	20.9	40.7
Selenium	mg/kg	1.1	0.71	0.99	1.2	1.5	1	0.41 b	1.6
Mercury	mg/kg	0.074	0.18	0.12	0.14	0.12	0.15	0.093	0.19

j = Method blank contamination. The associated method blank contains the target analyte at a reportable level.
u = Not detected. Reporting limit shown.
b = Estimated result. Result is less than the reporting limit.

Table 4-13
Surface Soil Sample Results Compared to Site-Specific and Regional Background Concentrations
TOAR-FUDS, Tobyhanna, PA

Metal	Unit	Frequency of Detection	Range of Concentrations[2] (mg/kg)	Background Samples[3]		Monroe County[4]		Pennsylvania[5]	
				Mean	Maximum	Mean	Maximum	Mean	Maximum
Antimony	mg/kg	38 / 44	0.45 - 10	0.72	0.99	NA	NA	0.1	1.0
Arsenic	mg/kg	44 / 44	2.0 - 22.7	4.92	8.8	NA	NA	12.9	31
Beryllium[1]	mg/kg	36 / 44	0.055 - 1.7	0.52	0.75	NA	NA	1.6	3
Cadmium	mg/kg	31 / 44	0.15 - 1.5	0.67	1.1	3.98	10.30	NA	NA
Chromium	mg/kg	44 / 44	2 - 11.6	5.18	9	23.42	115.00	52.8	100
Copper	mg/kg	44 / 44	3.7 - 167	8.76	12.6	18.93	81.00	37.0	70
Lead	mg/kg	44 / 44	23.4 - 611	51.82	115	32.77	82.00	22.8	30
Mercury	mg/kg	44 / 44	0.051 - 0.47	0.13	0.21	NA	NA	0.1	0.25
Nickel	mg/kg	44 / 44	1.0 - 13.5	3.16	6.2	12.73	32.40	23.8	50
Selenium	mg/kg	44 / 44	0.38 - 4.7	1.20	1.9	NA	NA	0.5	1.26
Silver	mg/kg	27 / 44	0.039 - 1.2	0.67	1.1	NA	NA	NA	NA
Thallium[1]	mg/kg	9 / 44	0.59 - 1.4	0.78	1.9	NA	NA	0.8	12.79
Zinc	mg/kg	44 / 44	10.9 - 154	31.74	61.8	186.70	420.00	80.8	155

NA = Not available

[1]Beryllium and Thallium were not detected in site-specific background samples. The mean was calculated using one-half the detection limit for each sample. The maximum value is the maximum detection limit for all samples.

[2]Concentrations detected during WESTON 2004 RI based on biased-high sampling locations (i.e. within known impact areas).

3Background soil samples collected at TOAR-FUDS in 2004.

[4]Source: Ciolkosz, Stehouwer, and Amistadi, 1998.

[5]Source: Shacklette and Boerngen, 1984.

Table 4-14
Surface Soil Samples - 2004 WESTON RI
Explosives Results
TOAR-FUDS, Tobyhanna, PA

	Field Sample ID	F2-SS-4257-002	F2A-SS-4257-001	F2A-SS-4257-002	F2-SS-4257-001	F3-SS-4257-001	F3-SS-4257-002	F4-SS-4258-001	F4-SS-4258-002	F4-SS-4258-102
	Sample Date	9/13/2004	9/13/2004	9/13/2004	9/13/2004	9/13/2004	9/13/2004	9/14/2004	9/14/2004	9/14/2004
	Location ID	F2-33-002	F2A-SS-001	F2A-SS-002	F2-SS-001	F3-SS-001	F3-SS-002	F4-SS-001	F4-SS-002	F4-SS-102
	Depth (in)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Parameter	Units									
2,4,6-Trinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
2,4-Dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
RDX	mg/kg	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
4-Amino-2,6-dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
HMX	mg/kg	0.5 u	0.069 j	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
2-Amino-4,6-dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
Tetryl	mg/kg	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u
2,6-Dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
2-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
Nitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
3-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
1,3,5-Trinitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
1,3-Dinitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
4-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u

	Field Sample ID	F5-SS-4257-001	F5-SS-4257-002	T10-SS-4258-001	T10-SS-4258-002	T10-SS-4258-003	T11-SS-4259-001	T1-SS-4257-001	T11-SS-4259-002	T11-SS-4259-003
	Sample Date	9/13/2004	9/13/2004	9/14/2004	9/14/2004	9/14/2004	9/15/2004	9/13/2004	9/15/2004	9/15/2004
	Location ID	F5-SS-001	F5-SS-002	T10-SS-001	T10-SS-002	T10-SS-003	T11-SD-001	T11-SS-001	T11-SS-002	T11-SS-003
	Depth (in)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Parameter	Units									
2,4,6-Trinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
2,4-Dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
RDX	mg/kg	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
4-Amino-2,6-dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
HMX	mg/kg	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
2-Amino-4,6-dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
Tetryl	mg/kg	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u
2,6-Dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
2-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
Nitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
3-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
1,3,5-Trinitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
1,3-Dinitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
4-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u

j = Estimated result. Result is less than the reporting limit.
u = Not detected. Reporting limit shown.

Table 4-14 (continued)
Surface Soil Samples - 2004 WESTON RI
Explosives Results
TOAR-FUDS, Tobyhanna, PA

	Field Sample ID	T1-SS-4257-002	T1-SS-4257-003	T2-SS-4251-001	T2-SS-4251-002	T2-SS-4251-003	T3-SS-4251-001	T3-SS-4251-002	T3-SS-4251-003	T3-SS-4251-103
	Sample Date	9/13/2004	9/13/2004	9/7/2004	9/7/2004	9/7/2004	9/7/2004	9/7/2004	9/7/2004	9/7/2004
	Location ID	T1-SS-002	T1-SS-003	T2-SS-001	T2-SS-002	T2-SS-003	T3-SS-001	T3-SS-002	T3-SS-003	T3-SS-103
	Depth (in)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Parameter	Units									
2,4,6-Trinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
2,4-Dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
RDX	mg/kg	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
4-Amino-2,6-dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
HMX	mg/kg	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
2-Amino-4,6-dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
Tetryl	mg/kg	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u
2,6-Dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
2-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
Nitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
3-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
1,3,5-Trinitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
1,3-Dinitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
4-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u

	Field Sample ID	T4-SS-4251-001	T4-SS-4251-002	T4-SS-4251-003	T6-SS-4259-001	T6-SS-4259-002	T6-SS-4259-003	T6-SS-4259-102	T7-SS-4258-001	T7-SS-4258-003
	Sample Date	9/7/2004	9/7/2004	9/7/2004	9/15/2004	9/15/2004	9/15/2004	9/15/2004	9/14/2004	9/14/2004
	Location ID	T4-SS-001	T4-SS-002	T4-SS-003	T6-SS-001	T6-SS-002	T6-SS-003	T6-SS-102	T7-SS-001	T7-SS-003
	Depth (in)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Parameter	Units									
2,4,6-Trinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
2,4-Dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
RDX	mg/kg	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
4-Amino-2,6-dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
HMX	mg/kg	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
2-Amino-4,6-dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
Tetryl	mg/kg	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u
2,6-Dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
2-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
Nitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
3-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
1,3,5-Trinitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
1,3-Dinitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
4-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u

j = Estimated result. Result is less than the reporting limit.
u = Not detected. Reporting limit shown.

Table 4-14 (continued)
Surface Soil Samples - 2004 WESTON RI
Explosives Results
TOAR-FUDS, Tobyhanna, PA

	Field Sample ID	T7-SS-4258-103	T8-SS-4258-001	T8-SS-4258-002	T8-SS-4258-003	T9-SS-4258-001	T9-SS-4258-002	T9-SS-4258-003	T7-SS-4258-002
	Sample Date	9/14/2004	9/14/2004	9/14/2004	9/14/2004	9/14/2004	9/14/2004	9/14/2004	9/14/2004
	Location ID	T7-SS-103	T8-SS-001	T8-SS-003	T8-SS-003	T9-SS-001	T9-SS-002	T9-SS-003	TOSR-T7-SS-002
	Depth (in)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Parameter	Units								
2,4,6-Trinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
2,4-Dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
RDX	mg/kg	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
4-Amino-2,6-dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
HMX	mg/kg	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
2-Amino-4,6-dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
Tetryl	mg/kg	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u
2,6-Dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
2-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
Nitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
3-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
1,3,5-Trinitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
1,3-Dinitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
4-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u

j = Estimated result. Result is less than the reporting limit.
u = Not detected. Reporting limit shown.

Table 4-15
Sediment Samples - 2004 WESTON RI
Metals Results
TOAR-FUDS, Tobyhanna, PA

	Field Sample ID	RA11-SD-4259-00	T11-SD-4252-001	T11-SD-4252-101	T1-SD-4252-001	T3-SD-4252-001	T6-SD-4252-001
	Sample Date	9/15/2004	9/8/2004	9/8/2004	9/8/2004	9/8/2004	9/8/2004
	Location ID	RA11-SD001	T11-SD-001	T11-SD-101	T1-SD-001	T3-SD-001	T6-SD-001
	Depth (in)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Parameter	**Units**						
Antimony	mg/kg	0.63 b	1.3 u	1.6 u	3.7 u	6.1 u	3.7 u
Arsenic	mg/kg	6.2	4.7	4.5	2.2 b	4.1 b	2.8 b
Beryllium	mg/kg	0.97 j	0.2 b	0.14 b	1.5 u	2.4 u	1.5 u
Cadmium	mg/kg	0.65 b	0.57 b	0.56 b	0.66 b	1.7 b	0.99 b
Chromium	mg/kg	3.7	12.5	11	4.9	3.6	5.6
Copper	mg/kg	1.6 bj	6.5 j	10.5 j	9 bj	31.5 j	20.1 j
Lead	mg/kg	23.4	8.6	15.7	44.6	113	80.1
Mercury	mg/kg	0.052 u	0.04 b	0.12	0.1 b	0.21	0.26
Nickel	mg/kg	11.5	8.9	8.1	4.8 b	7.6 b	6.8 b
Selenium	mg/kg	0.64 b	0.37 b	0.5 b	1.4 b	1.7 b	1.1 b
Silver	mg/kg	0.52 b	0.65 u	0.79 u	1.8 u	3.1 u	1.8 u
Thallium	mg/kg	1.6 u	1.3 u	1.6 u	3.7 u	6.1 u	3.7 u
Zinc	mg/kg	116	31.1	30.2	32	104	64.1

j = Method blank contamination. The associated method blank contains the target analyte at a reportable level.
u = Not detected. Reporting limit shown.
b = Estimated result. Result is less than the reporting limit.

Table 4-16
Sediment Sample Results Compared to Site-Specific Background Concentrations
TOAR-FUDS, Tobyhanna, PA

Metal	Unit	Frequency of Detection	Range of Concentrations[1] (mg/kg)	TYAD Background Concentrations[2]		
				Mean	Maximum	Reporting Limit
Antimony	mg/kg	1 / 6	0.63	ND	ND	7.14
Arsenic	mg/kg	6 / 6	2.2 - 6.2	4.70	28.50	NA
Beryllium	mg/kg	3 / 6	0.14 - 0.97	ND	ND	0.5
Cadmium	mg/kg	6 / 6	0.56 - 1.7	0.62	4.35	NA
Chromium	mg/kg	6 / 6	3.6 - 12.5	ND	ND	4.05
Copper	mg/kg	6 / 6	1.6 - 31.5	14.55	25.80	NA
Lead	mg/kg	6 / 6	8.6 - 113	110.16	780.00	NA
Mercury	mg/kg	5 / 6	0.04 - 0.26	ND	ND	0.05
Nickel	mg/kg	6 / 6	4.8 - 11.5	6.20	19.90	NA
Selenium	mg/kg	6 / 6	0.37 - 1.7	0.26	2.16	NA
Silver	mg/kg	1 / 6	0.52	ND	ND	0.589
Thallium	mg/kg	0 / 6	NA	ND	ND	6.62
Zinc	mg/kg	6 / 6	30.2 - 116	161.35	328.00	NA

ND = Metal not detected in background sediment samples.
[1]Concentrations detected during WESTON 2004 RI based on biased-high sampling locations (i.e. known impact areas).
[2]Source: TYAD Ecological Risk Assessment, 1997.

Table 4-17
Sediment Samples - 2004 WESTON RI
Explosives Results
TOAR-FUDS, Tobyhanna, PA

	Field Sample ID	RA11-SD-4259-00	T11-SD-4252-001	T11-SD-4252-101	T1-SD-4252-001	T3-SD-4252-001	T6-SD-4252-001
	Sample Date	9/15/2004	9/8/2004	9/8/2004	9/8/2004	9/8/2004	9/8/2004
	Location ID	RA11-SD001	T11-SD-001	T11-SD-101	T1-SD-001	T3-SD-001	T6-SD-001
	Depth (in)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Parameter	Units						
2,4,6-Trinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
2,4-Dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
RDX	mg/kg	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
4-Amino-2,6-dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
HMX	mg/kg	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
2-Amino-4,6-dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
Tetryl	mg/kg	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u	0.65 u
2,6-Dinitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
2-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
Nitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
3-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
1,3,5-Trinitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
1,3-Dinitrobenzene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u
4-Nitrotoluene	mg/kg	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u	0.25 u

u = Not detected. Reporting limit shown.

Table 4-18
Surface Water Samples - 2004 WESTON RI
Metals Results
TOAR-FUDS, Tobyhanna, PA

	Field Sample ID	RA11-SW-4259-00	T11-SW-4252-001	T11-SW-4252-101	T1-SW-4252-001	T3-SW-4252-001	T6-SW-4252-001
	Sample Date	9/15/2004	9/8/2004	9/8/2004	9/8/2004	9/8/2004	9/8/2004
	Location ID	RA11-SW001	T11-SW-001	T11-SW-101	T1-SW-001	T3-SW-001	T6-SW-001
	Depth (in)	NA	NA	NA	NA	NA	NA
Parameter	Units						
Antimony, Total	ug/l	10 u	10 u	10 u	10 u	10 u	10 u
Arsenic, Total	ug/l	10 u	10 u	5.4 b	10 u	10 u	10 u
Beryllium, Total	ug/l	1.6 bj	4 u	4 u	4 u	4 u	4 u
Cadmium, Total	ug/l	5 u	5 u	1 b	5 u	5 u	5 u
Chromium,TOTAL	ug/l	5 u	2.8 b	3.7 b	5 u	5 u	5 u
Copper,TOTAL	ug/l	25 u	8.1 bj	11.5 bj	1.9 bj	6.4 bj	3.9 bj
Lead,TOTAL	ug/l	3 u	15.9	31.5	4.6	27	9.7
Mercury, Total	ug/l	0.2 u	0.2 u	0.13 b	0.2 u	0.2 u	0.2 u
Nickel,TOTAL	ug/l	40 u	40 u	2.6 b	40 u	1.4 b	3.2 b
Selenium,TOTAL	ug/l	5 u	5 u	5 u	5 u	3.8 b	5 u
Silver,TOTAL	ug/l	0.33 b	5 u	5 u	5 u	5 u	5 u
Thallium, Total	ug/l	10 u	10 u	10 u	10 u	10 u	10 u
Zinc,TOTAL	ug/l	7 b	21	27.7	12.1 b	22.9	11.9 b
Hardness, Total	mg/l	12.9 b	2 b	2.5 b	5.3 b	3.5 b	5.3 b

NA = Not applicable.
j = Method blank contamination. The associated method blank contains the target analyte at a reportable level.
u = Not detected. Reporting limit shown.
b = Estimated result. Result is less than the reporting limit.

Table 4-19
Surface Water Sample Results Compared to Site-Specific Background Concentrations
TOAR-FUDS, Tobyhanna, PA

Metal	Unit	Frequency of Detection	Range of Concentrations[1] (µg/kg)	TYAD Background Concentrations[2]		
				Mean	Maximum	Reporting Limit
Antimony	mg/kg	0 / 6	NA	ND	ND	7.14
Arsenic	mg/kg	1 / 6	5.4	ND	ND	2.54
Beryllium	mg/kg	4 / 6	1.5 - 1.7	ND	ND	5.00
Cadmium	mg/kg	1 / 6	1	ND	ND	4.01
Chromium	mg/kg	2 / 6	2.8 - 3.7	ND	ND	6.02
Copper	mg/kg	5 / 6	1.9 - 11.5	4.68	23.00	NA
Lead	mg/kg	5 / 6	4.6 - 31.5	0.89	4.12	NA
Mercury	mg/kg	1 / 6	0.13	ND	ND	0.243
Nickel	mg/kg	3 / 6	1.4 - 3.2	ND	ND	34.30
Selenium	mg/kg	1 / 6	3.8	ND	ND	3.02
Silver	mg/kg	1 / 6	0.33	ND	ND	4.60
Thallium	mg/kg	0 / 6	NA	ND	ND	6.99
Zinc	mg/kg	6 / 6	7 - 27.7	10.94	22.20	NA

ND = Metal not detected in background surface water samples.

NA = Not applicable. Reporting limits only shown for metals that were not detected.

Table 4-20
Surface Water Samples - 2004 WESTON RI
Explosives Results
TOAR-FUDS, Tobyhanna, PA

	Field Sample ID	RA11-SW-4259-00	T11-SW-4252-001	T11-SW-4252-101	T1-SW-4252-001	T3-SW-4252-001	T6-SW-4252-001
	Sample Date	9/15/2004	9/8/2004	9/8/2004	9/8/2004	9/8/2004	9/8/2004
	Location ID	RA11-SW001	T11-SW-001	T11-SW-101	T1-SW-001	T3-SW-001	T6-SW-001
	Depth (in)	NA	NA	NA	NA	NA	NA
Parameter	**Units**						
2,4,6-Trinitrotoluene	ug/l	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u
2,4-Dinitrotoluene	ug/l	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u
RDX	ug/l	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
4-Amino-2,6-dinitrotoluene	ug/l	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u
HMX	ug/l	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u	0.5 u
2-Amino-4,6-dinitrotoluene	ug/l	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u
Tetryl	ug/l	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u
2,6-Dinitrotoluene	ug/l	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u
2-Nitrotoluene	ug/l	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u
Nitrobenzene	ug/l	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u
3-Nitrotoluene	ug/l	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u
1,3,5-Trinitrobenzene	ug/l	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u
1,3-Dinitrobenzene	ug/l	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u
4-Nitrotoluene	ug/l	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u

u = Not detected. Reporting limit shown.

Table 4-21
Soil Sample Results from Test Pits at FP #1 – 2004 WESTON RI
Metals and All Other Positive Results
TOAR-FUDS, Tobyhanna, PA

	Field Sample ID	TOAR-FP1-TP-4287-004	TOAR-FP1-TP-4287-007	Background Soil Concentrations					
	Sample Date	10/13/2004	10/13/2004						
	Location ID	FP1-TP-004	FP1-TP-007	Background Samples[a]		Monroe County[b]		Pennsylvania[c]	
	Depth (ft)	7	3						
Parameter	Units			Mean	Maximum	Mean	Maximum	Mean	Maximum
Metals									
Antimony	mg/kg	0.43 b	2.7	1.15	1.9	NA	NA	0.1	1.0
Arsenic	mg/kg	25.1	5.3	4.92	8.8	NA	NA	12.9	31
Beryllium	mg/kg	0.5	0.2 b	0.52	0.75	NA	NA	1.6	3
Cadmium	mg/kg	0.92	0.6	0.67	1.1	3.98	10.30	NA	NA
Chromium	mg/kg	9.5 j	7 j	5.18	9	23.42	115.00	52.8	100
Copper	mg/kg	12.9 j	98.8 j	8.76	12.6	18.93	81.00	37.0	70
Lead	mg/kg	15.2 j	316 j	51.82	115	32.77	82.00	22.8	30
Mercury	mg/kg	0.039 u	0.067	0.13	0.21	NA	NA	0.1	0.25
Nickel	mg/kg	15.7 j	8.4 j	3.16	6.2	12.73	32.4	23.8	50
Selenium	mg/kg	0.46 b	0.58 u	1.20	1.9	NA	NA	0.5	1.26
Silver	mg/kg	0.065 bj	0.11 bj	0.67	1.1	NA	NA	NA	NA
Thallium	mg/kg	1.2 u	1.2 u	1.56	1.9	NA	NA	0.8	12.79
Zinc	mg/kg	50	72.5	31.74	61.8	186.7	420	80.8	155
Pesticides									
4,4-DDT	µg/kg	0.28 j	2 u	NA	NA	NA	NA	NA	NA
VOCs									
Acetone	µg/kg	19 u	91	NA	NA	NA	NA	NA	NA

j = Method blank contamination. The associated method blank contains the target analyte at a reportable level.
u = Not detected. Reporting limit shown.
b = Estimated result. Result is less than the reporting limit.
aBackground soil samples collected at TOAR-FUDS in 2004.

[b]Source: Ciolkosz, Stehouwer, and Amistadi, 1998.

[c]Source: Shacklette and Boerngen, 1984.

NA = Not applicable.

Table 4-22
Revised UXO Distribution by Type – 2004 WESTON RI
TOAR-FUDS, Tobyhanna, PA

UXO Source Area Depth		UXO Distribution by Type 37mm 5%	75-81mm 51%	155mm 44%	Totals
Lake Watawga Area	**Totals**	**0**	**1**	**1**	**2**
0-6 inch		0	1	1	2
6-12 inch		0	0	0	0
>12 inch		0	0	0	0
FP - Game	**Totals**	**0**	**0**	**0**	**0**
FP - Park	**Totals**	**0**	**0**	**0**	**0**
Impact Area - Game	**Totals**	**0**	**19**	**16**	**35**
0-6 inch		0	14	12	26
6-12 inch		0	4	2	6
>12 inch		0	1	2	3
Impact Area - Park	**Totals**	**4**	**19**	**15**	**38**
0-6 inch		3	17	12	32
6-12 inch		1	2	2	5
>12 inch		0	0	1	1
Buffer Zone - Game	**Totals**	**0**	**1**	**2**	**3**
0-6 inch		0	0	2	2
6-12 inch		0	1	0	1
>12 inch		0	0	0	0
Buffer Zone - Park	**Totals**	**0**	**0**	**0**	**0**
0-6 inch		0	0	0	0
6-12 inch		0	0	0	0
>12 inch		0	0	0	0
Other - Game	**Totals**	**0**	**0**	**0**	**0**
Other - Park	**Totals**	**0**	**0**	**0**	**0**

Table 4-23
Revised UXO Distribution by Depth – 2004 WESTON RI
TOAR-FUDS, Tobyhanna, PA

UXO Source Area UXO Type	UXO Distribution by Depth	0-6 inch 79%	6-12 inch 15%	>12 inch 5%	Totals
Lake Watawga Area	**Totals**	**2**	**0**	**0**	**2**
37mm		0	0	0	0
75-81mm		1	0	0	1
155mm		1	0	0	1
FP - Game	**Totals**	**0**	**0**	**0**	**0**
FP - Park	**Totals**	**0**	**0**	**0**	**0**
Impact Area - Game	**Totals**	**26**	**6**	**3**	**35**
37mm		0	0	0	0
75-81mm		14	4	1	19
155mm		12	2	2	16
Impact Area - Park	**Totals**	**32**	**5**	**1**	**38**
37mm		3	1	0	4
75-81mm		17	2	0	19
155mm		12	2	1	15
Buffer Zone - Game	**Totals**	**2**	**1**	**0**	**3**
37mm		0	0	0	0
75-81mm		0	1	0	1
155mm		2	0	0	2
Buffer Zone - Park	**Totals**	**0**	**0**	**0**	**0**
37mm		0	0	0	0
75-81mm		0	0	0	0
155mm		0	0	0	0
Other - Game	**Totals**	**0**	**0**	**0**	**0**
Other - Park	**Totals**	**0**	**0**	**0**	**0**

Table 4-24
Summary of All UXO and MD Recovered To Date at TOAR-FUDS Based on Revised CSM
TOAR-FUDS, Tobyhanna, PA

PARK

	Buffer Park					Impact Park					Other Park					Lake Watawga					Totals				
Investigations	Total Acreage	Wet Acreage[1]	Acres Investigated	UXO Items Found	MD Items Found	Total Acreage	Wet Acreage	Acres Investigated	UXO Items Found	MD Items Found	Total Acreage	Wet Acreage	Acres Investigated	UXO Items Found	MD Items Found	Total Acreage	Wet Acreage	Acres Investigated	UXO Items Found	MD Items Found	**Total Acreage**	**Wet Acreage**	**Acres Investigated**	**UXO Items Found**	**MD Items Found**
2004 WESTON RI - DGM	2,908	554	8.91	0	16	1,357	371	13.03	31	1,857	3,790	525	9.20	0	0	265	151	0.42	0	8	**8,320**	**1,600**	**31.56**	**31**	**1,881**
2004 WESTON RI - IAR			54.29	0				27.87	7				49.37	0				54.05	2				**185.58**	**9**	
2004 WESTON TCRA			-	-	-			-	-	-			0	0	-			0	0	-			**0**	**0**	**-**
2004 WESTON Site Visit[2]			-	-	-			-	3	-			-	-	-			-	-	-			**0**	**3**	**-**
2004 CENAB Site Visit[3]			-	-	-			-	-	-			-	-	-			-	2	3			**0**	**2**	**-**
1998 HFA TCRA[4]			5	5	-			200.5	273	-			-	-	-			-	-	-			**205.5**	**278**	**-**
TOTALS	**2,908**	**554**	**68.2**	**5**	**16**	**1,357**	**371**	**241.4**	**314**	**1,857**	**3,790**	**525**	**58.57**	**0**	**0**	**265**	**151**	**54.47**	**4**	**11**	**8,320**	**1,600**	**422.64**	**323**	**1,881**
% of AOI Inaccessible[5]	**-**	**19%**	**-**	**-**	**-**	**-**	**27%**	**-**	**-**	**-**	**-**	**14%**	**-**	**-**	**-**	**-**	**57%**	**-**	**-**	**-**	**-**	**19%**	**-**	**-**	**-**
% of AOI Investigated	**-**	**-**	**2.3%**	**-**	**-**	**-**	**-**	**17.8%**	**-**	**-**	**-**	**-**	**1.5%**	**-**	**-**	**-**	**-**	**20.6%**	**-**	**-**	**-**	**-**	**5.1%**	**-**	**-**

GAME

	Buffer Game					Impact Game					Other Game					Totals				
Investigations	Total Acreage	Wet Acreage	Acres Investigated	UXO Items Found	MD Items Found	Total Acreage	Wet Acreage	Acres Investigated	UXO Items Found	MD Items Found	Total Acreage	Wet Acreage	Acres Investigated	UXO Items Found	MD Items Found	**Total Acreage**	**Wet Acreage**	**Acres Investigated**	**UXO Items Found**	**MD Items Found**
2004 WESTON RI - DGM	7,304	1,519	9.06	2	107	1,281	375	19.03	27	1361	4,195	1,798	13.66	0	16	**12,780**	**3,692**	**41.75**	**29**	**1,484**
2004 WESTON RI - IAR			36.25	1				15.85	8				34.40	0				**86.5**	**9**	
2004 WESTON TCRA			20	1	15			-	-	18			6.87	0				**26.87**	**1**	**33**
2004 WESTON Site Visit			-	-	-			-	-	-			-	-				**0**	**0**	**-**
2004 CENAB Site Visit			-	-	-			-	-	-			-	-				**0**	**0**	**-**
1998 HFA TCRA[4]			-	-	-			-	-	-			-	-				**0**	**0**	**-**
TOTALS	**7,304**	**1,519**	**65.31**	**4**	**122**	**1,281**	**375**	**34.88**	**35**	**1379**	**4195**	**1,798**	**54.93**	**0**	**16**	**12,780**	**3,692**	**155.12**	**39**	**1,517**
% of AOI Inaccessible[5]	**-**	**21%**	**-**	**-**	**-**	**-**	**29%**	**-**	**-**	**-**	**-**	**43%**	**-**	**-**	**-**	**-**	**29%**	**-**	**-**	**-**
% of AOI Investigated	**-**	**-**	**0.9%**	**-**	**-**	**-**	**-**	**2.7%**	**-**	**-**	**-**	**-**	**1.3%**	**-**	**-**	**-**	**-**	**1.2%**	**-**	**-**

ENTIRE SITE

	TOAR-FUDS				
SITE TOTALS	**Total Acreage**	**Wet Acreage**	**Acres Investigated**	**UXO Items Found**	**MD Items Found**
TOTALS	**21,100**	**5,292**	**578**	**362**	**3,398**
% of AOI Inaccessible[5]	**-**	**25%**	**-**	**-**	**-**
% of Site Investigated	**-**	**-**	**2.7%**	**-**	**-**

1Wet acreage based on 2000 coverage of TOAR-FUDS and includes lakes, ponds, streams, wetlands, etc.

[2]Acres investigated during 2004 WESTON Site Visit were investigated by visual searching and are approximate.

[3]Acres investigated during 2004 CENAB Site Visit were investigated by visual searching and are approximate.

[4]Acres investigated during 1998 HFA TCRA were investigated using Mag and Dig. Total acres investigated were calculated in HFA report. Acres investigated in Buffer Park and Impact Park are approximate.

[5]Inaccessible = Unable to access wet areas with detection, positioning, or excavation equipment.

Table 4-25
Revised Areas Investigated - 2004 WESTON RI
TOAR-FUDS, Tobyhanna, PA

Area	Approx. Acres	Min No. of Acres To Be Investigated[1]	Acres Intrusively Investigated[2]				
			Grids	Transects[3]	DGM Total	IAR	Total
Tobyhanna State Park							
Buffer Zones	2,908	6	1.12	7.79	8.91	54.29	63.20
Impact Areas	1,357	6	6.22	6.81	13.03	27.87	40.90
Other Areas	3,790	6	3.74	5.46	9.20	49.37	58.57
Lake Watawga Area[4]	265	NA	0.00	0.42	0.42	54.05	54.47
TOTALS	**8,320**	**18**	**11.08**	**20.48**	**31.56**	**185.58**	**217.14**
Pennsylvania State Gamelands Number 127							
Buffer Zones	7,304	6	1.15	7.91	9.06	36.25	45.31
Impact Areas	1,281	6	8.97	10.06	19.03	15.85	34.88
Other Areas	4,195	6	5.50	8.16	13.66	34.40	48.06
TOTALS	**12,780**	**18**	**15.62**	**26.13**	**41.75**	**86.50**	**128.25**

NA = Not applicable
[1]Minimum Acres based on UXO Estimator using risk basis of 0.5 UXO per acre and 95% confidence.
[2]Acres were mapped and targets were dug. Acres investigated along transects were calculated using a width of 5.34 ft.
[3]Acres investigated along transects were calculated using a width of 3 feet in areas where 37-mm UXO was found, and 5.34 feet in all other areas.
[4]Acres investigated as part of Lake Watawga include IAR acreage inside and outside the FUDS boundary.

Table 4-26
Revised UXO Density - 2004 WESTON RI
TOAR-FUDS, Tobyhanna, PA

Area	Total Approx. Acres	Total Acres Investigated	No. of UXO Found	UXO Density (items found/acre investigated)
Tobyhanna State Park - DGM				
Buffer Zone	2,908	8.91	0	0.000
Impact Areas	1,357	13.03	31	2.379
Other Areas	3,790	9.20	0	0.000
Lake Watawga Area	265	0.42	0	0.000
Tobyhanna State Park - IAR				
Buffer Zone	2,908	54.29	0	0.000
Impact Areas	1,357	27.87	7	0.251
Other Areas	3,790	49.37	0	0.000
Lake Watawga Area	265	54.05	2	0.037
Pennsylvania State Gamelands Number 127 - DGM				
Buffer Zone	7,304	9.06	2	0.221
Impact Areas	1,281	19.03	27	1.419
Other Areas	4,195	13.66	0	0.000
Pennsylvania State Gamelands Number 127 - IAR				
Buffer Zone	7,304	36.25	1	0.028
Impact Areas	1,281	15.85	8	0.505
Other Areas	4,195	34.40	0	0.000
TOTALS[1]	**21,100**	**345.39**	**78**	**-**

[1]Total acres investigated does not include 2004 WESTON TCRA or site visits.

Table 4-27
UXO Estimator Module 2 Output for Revised CSM
TOAR-FUDS, Tobyhanna, PA

Area	UXO Estimator Module 2 Input					UXO Estimator Module 2 Output		
	Total Approx. Acres	Total Acres Investigated	No. of UXO Found	Target Density	Confidence Level	Confidence Level (at 0.5 Target Density)	Average UXO Density Expected	Density (at 95% Confidence Level)
Tobyhanna State Park - DGM								
Buffer Zones	2,908	8.91	0	0.5	95%	98.85%	0.112	0.336
Impact Areas	1,357	13.03	31	0.5	95%	0%	2.455	3.206
Other Areas	3,790	9.20	0	0.5	95%	99.00%	0.108	0.325
Lake Watawga[1]	265	0.42	0	0.5	95%	-	-	-
Tobyhanna State Park - IAR								
Buffer Zones	2,908	54.29	0	0.5	95%	100%	0.018	0.054
Impact Areas	1,357	27.87	7	0.5	95%	96.89%	0.286	0.469
Other Areas	3,790	49.37	0	0.5	95%	100%	0.020	0.060
Lake Watawga[2]	265	54.05	2	0.5	95%	100.00%	0.072	0.147
Pennsylvania State Gamelands Number 127 - DGM								
Buffer Zones	7,304	9.06	2	0.5	95%	83.01%	0.331	0.695
Impact Areas	1,281	19.03	27	0.5	95%	0%	1.471	1.952
Other Areas	4,195	13.66	0	0.5	95%	99.89%	0.073	0.219
Pennsylvania State Gamelands Number 127 - IAR								
Buffer Zones	7,304	36.25	1	0.5	95%	100%	0.055	0.130
Impact Areas	1,281	15.85	8	0.5	95%	39.87%	0.567	0.908
Other Areas	4,195	34.40	0	0.5	95%	100%	0.029	0.087

[1]A minimal number of acres were investigated intrusively using DGM methods in the Lake Watawga area due to safety concerns. Therefore, UXO Estimator Module 2 was not used to analyze the Lake Watawga area.

[2]Acres investigated in the Lake Watawga Area using IAR methods includes acreage inside (14.20 acres) and outside (39.85 acres) the FUDS boundary. The UXO Estimator 2 Module Output was calculated using only the acreage investigated inside the FUDS boundary.

5. PRELMINARY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND TO BE CONSIDERED CRITERIA

Three categories of applicable or relevant and appropriate requirements (ARARs) are evaluated for the TOAR-FUDS, along with to be considered criteria (TBCs). The ARAR categories are: chemical-specific, location-specific, and action-specific. The preliminary ARARs and TBCs summarized in Table 5-1 will be further refined in the FS for the TOAR-FUDS.

Chemical-specific ARARs are 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. Chemical-specific ARARs have been identified to provide benchmarks with which to compare environmental sampling results for metals and explosives at the TOAR-FUDS. The benchmarks are used in the human health and ecological screening level risk assessments described in subsection 7.2.

Location-specific ARARs generally are restrictions placed on the concentration of hazardous substances or the conduct of activities to prevent damage to unique or sensitive areas, such as floodplains, wetlands, historic places, and sensitive ecosystems or habitats. Several location-specific ARARs have been identified. These location-specific ARARs will be reviewed prior to implementation of cleanup action alternatives at the TOAR-FUDS. The location-specific ARARs include protection of historical and archaeological resources, and protection of wildlife and habitat resources, including endangered species, fish, migratory birds, and wetlands.

Action-specific ARARs are usually technology or activity-based requirements or limitations placed on actions taken with respect to cleanup actions, or requirements to conduct certain actions to address particular circumstances at a site.

TBCs are used when no there are no ARARs, or when ARARs alone may not adequately protect human health and the environment.

Table 5-1 Preliminary Applicable or Relevant and Appropriate Requirements and To Be Considered Criteria

ARAR/TBC[1]	Citation	Applicability or Relevance
Chemical-Specific ARARs		
25 Pa. Code 250 – Administration of Land Recycling Program	Appendix A, Table 3a – Medium-Specific Concentrations (MSCs) for Organic Regulated Substances in Soil, Direct Contact Numeric Values, Residential (0-15 feet) and Non-Residential, surface soil (0-2 feet). Appendix A, Table 3b – MSCs for Organic Regulated Substances in Soil, Soil to Groundwater Numeric Values, Used Aquifers, TDS less than or equal to 2500, Residential (Generic Value) and Non-Residential (Generic Value). Appendix A, Table 4a – MSCs for Inorganic Regulated Substances in Soil, Direct Contact Numeric Values, Residential (0-15 feet) and Non-Residential, surface soil (0-2 feet). Appendix A, Table 4b – MSCs for Inorganic Regulated Substances in Soil, Soil to Groundwater Numeric Values, Used Aquifers, TDS less than or equal to 2500, Residential (Generic Value) and Non-Residential (Generic Value).	MSCs for organic and inorganic substances in soil were compared to results from soil and sediment samples collected at the TOAR-FUDS in order to evaluate risk associated with metals and explosives.
25 Pa. Code 16 – Water Quality Toxics Management Strategy-Statement of Policy	Appendix A, Table 1 – Water Quality Criteria for Toxic Substances.	Water quality criteria for fish and aquatic life (continuous and maximum concentrations) and human health were compared to results from surface water samples collected at the TOAR-FUDS in order to evaluate risk associated with metals and explosives.
Location-Specific ARARs – Location of an action within an area where it may cause irreparable harm, loss, or destruction of significant artifacts or historic landmarks		
36 CFR 800, excluding section 800.8 – Protection of historic properties (Section 106 of the National Historic Preservation Act, as amended)	(a) *Purposes of the section 106 process.* Section 106 of the National Historic Preservation Act requires Federal agencies to take into account the effects of their undertakings on historic properties and afford the Council a reasonable opportunity to comment on such undertakings.	Historic property may exist at the TOAR-FUDS. The procedures in 36 CFR 800 describe how Federal agencies meet these statutory responsibilities: by identifying historic properties potentially affected by the undertaking, assessing the effects, and seeking ways to avoid, minimize, or mitigate any adverse effects on historic properties.

Table 5-1 Preliminary Applicable or Relevant and Appropriate Requirements and To Be Considered Criteria (continued)

ARAR/TBC[1]	Citation	Applicability or Relevance
33 CFR 320.4 – General policies for evaluating permit applications.	(1) Most wetlands constitute a productive and valuable public resource, the unnecessary alteration or destruction of which should be discouraged as contrary to the public interest. For projects to be undertaken or partially or entirely funded by a federal, state, or local agency, additional requirements on wetlands considerations are stated in Executive Order 11990, dated 24 May 1977. (4) No permit will be granted which involves the alteration of wetlands identified as important by paragraph (b)(2) of this section or because of provisions of paragraph (b)(3) of this section unless the district engineer concludes, on the basis of the analysis required in paragraph (a) of this section, that the benefits of the proposed alteration outweigh the damage to the wetlands resource.	Approximately 25% of the TOAR-FUDS consists of wet areas. This Part and the Parts that follow (33 CFR Parts 321-330) prescribe the statutory authorities, and general and special policies and procedures applicable to the review of applications for Department of the Army (DA) permits for controlling certain activities in waters of the United States or the oceans. This part identifies the various federal statutes which require that DA permits be issued before these activities can be lawfully undertaken; and related Federal laws and the general policies applicable to the review of those activities.
Executive Order 11990	Sec. 5. In carrying out the activities described in Section I of this Order, each agency shall consider factors relevant to a proposal's effect on the survival and quality of the wetlands. Among these factors are: (a) public health, safety, and welfare, including water supply, quality, recharge and discharge; pollution; flood and storm hazards; and sediment and erosion; (b) maintenance of natural systems, including conservation and long term productivity of existing flora and fauna, species and habitat diversity and stability, hydrologic utility, fish, wildlife, timber, and food and fiber resources; and (c) other uses of wetlands in the public interest, including recreational, scientific, and cultural uses.	Approximately 25% of the TOAR-FUDS consists of wet areas. This order was issued to avoid to the extent possible the long and short term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative.

Table 5-1 Preliminary Applicable or Relevant and Appropriate Requirements and To Be Considered Criteria (continued)

ARAR/TBC[1]	Citation	Applicability or Relevance
16 U.S.C. 1536 (Endangered Species Act of 1973, as amended)	2) Each Federal agency shall, in consultation with and with the assistance of the Secretary, insure that any action authorized, funded, or carried out by such agency (hereinafter in this section referred to as an "agency action") is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species which is determined by the Secretary, after consultation as appropriate with affected States, to be critical, unless such agency has been granted an exemption for such action by the Committee pursuant to subsection (h) of this section. In fulfilling the requirements of this paragraph each agency shall use the best scientific and commercial data available.	Endangered and threatened species are present at the TOAR-FUDS, as described in Section 2 of the RI report. The purposes of this section of the Endangered Species Act are to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve the purposes of the treaties and conventions set forth in subsection (a) of this section. This Act requires interagency cooperation to ensure that authorized actions do not jeopardize the continued existence of endangered or threatened species, or their habitats.
Action-Specific ARARs		
25 Pa. Code 102.11 – Erosion and sediment control BMPs; General requirements	(a) A person conducting or proposing to conduct an earth disturbance activity shall design, implement and maintain BMPs to minimize the potential for accelerated erosion and sedimentation in order to protect, maintain, reclaim and restore water quality and existing and designated uses. Various BMPs and their design standards are listed in the Erosion and Sediment Pollution Control Program Manual (Manual), Commonwealth of Pennsylvania, Department of Environmental Protection, No. 363-2134-008 (January 1996), as amended and updated. (b) BMPs and design standards other than those listed in the Manual may be used when a person conducting or proposing to conduct an earth disturbance activity demonstrates to the Department or a county conservation district that the alternate BMP or design standard minimizes accelerated erosion and sedimentation to achieve the regulatory standards in subsection (a).	UXO removal activities would require excavation of some kind. 25 Pa. Code 102 requires persons proposing or conducting earth disturbance activities to develop, implement and maintain BMPs to minimize the potential for accelerated erosion and sedimentation.

Table 5-1 Preliminary Applicable or Relevant and Appropriate Requirements and To Be Considered Criteria (continued)

ARAR/TBC[1]	Citation	Applicability or Relevance
25 Pa. Code 102.22 – Erosion and sediment control BMPs; Permanent stabilization	(a) Upon completion of an earth disturbance activity or any stage or phase of an activity, the site shall be immediately seeded, mulched or otherwise protected from accelerated erosion and sedimentation. (b) Erosion and sediment control BMPs shall be implemented and maintained until the permanent stabilization is completed. (c) For an earth disturbance activity or any stage or phase of an activity to be considered permanently stabilized, the disturbed areas shall be covered with one of the following: (1) A minimum uniform 70% perennial vegetative cover, with a density capable of resisting accelerated erosion and sedimentation. (2) An acceptable BMP which permanently minimizes accelerated erosion and sedimentation.	UXO removal activities would require excavation of some kind. 25 Pa. Code 102 requires persons proposing or conducting earth disturbance activities to develop, implement and maintain BMPs to minimize the potential for accelerated erosion and sedimentation.
25 Pa. Code 123.2 – Standards for contaminants; Fugitive particulate matter	A person may not permit fugitive particulate matter to be emitted into the outdoor atmosphere from a source specified in § 123.1(a)(1)—(9) (relating to prohibition of certain fugitive emissions) if the emissions are visible at the point the emissions pass outside the person's property.	UXO removal activities would require excavation of some kind, which could result in fugitive particulate matter. 25 Pa. Code 123 provides standards for contaminants in air emissions.
40 CFR 264 Subpart X – Standards for owners and operators of hazardous waste treatment, storage, and disposal facilities; Miscellaneous units	264.601 A miscellaneous unit must be located, designed, constructed, operated, maintained, and closed in a manner that will ensure protection of human health and the environment.	UXO disposal could require the use of technologies defined as "miscellaneous units" in Subpart X, including open burn/open detonation (OB/OD) units, shredders, crushers, etc. Subpart X outlines procedures for issuing permits to miscellaneous units that treat, store, or dispose of hazardous waste. Miscellaneous units include OB/OD units, enclosed combustion devices, carbon and catalyst regeneration units, thermal desorption units, shredders, crushers, filter presses and geologic repositories. Subpart X does not specify minimum technology requirements or monitoring requirements for miscellaneous units. Subpart X specifies an environmental performance standard that must be met through conformance with appropriate design, operating, and monitoring requirements.

Table 5-1 Preliminary Applicable or Relevant and Appropriate Requirements and To Be Considered Criteria (continued)

ARAR/TBC[1]	Citation	Applicability or Relevance
TBCs		
Memo, DoD and EPA, Interim Final, 7 March 2000 – "DoD and EPA Interim Final Management Principles for Implementing Response Actions at Closed, Transferring, and Transferred (CTT) Ranges"	A permanent record of the data gathered to characterize a site and a clear audit trail of pertinent data analysis and resulting decisions and actions are required. To the maximum extent practicable, the permanent record shall include sensor data that is digitally-recorded and geo-referenced.	This document provides interim guidance for ongoing response actions addressing UXO at CTT Ranges, such as the TOAR-FUDS.

[1]The preliminary ARARs listed in Table 5-1 are subject to review.

6. CONTAMINANT FATE AND TRANSPORT

Detailed evaluation of fate and transport is generally performed to support the more directed sampling activities and detailed findings of a RI and not those of the more exploratory-type data collected at the SI level. The sampling conducted for MC at the TOAR-FUDS was conducted at the SI level. However, a discussion of fate and transport has been included in this RI report to support the evaluations of COPCs and related issues with respect to human health and environmental risks discussed in subsection 7.2.

As discussed in subsection 7.2, of the analytes tested for during the RI at the TOAR-FUDS, only three metals, lead, copper and antimony, were found at concentrations that exceeded background levels as well as EPA Region III risk-based concentrations (RBCs) (EPA, 2004), and/or Pennsylvania Land Recycling Program Act 2 concentrations (published as medium-specific concentrations [MSCs]) (PADEP, 2001). Specifically, lead and antimony were identified as being statistically above background levels with respect to human health concerns while lead, copper and antimony were determined to be statistically above background levels from an ecological perspective.

Potential migration pathways for these metals include: airborne dust particles; waterborne particles in storm or river runoff; dissolution in storm runoff or other surface water movement; and dissolution in groundwater. Airborne dust is not considered a problem, as the TOAR-FUDS is highly vegetated, and not subject to disturbance or to broad scale erosion. As discussed below, lead, copper and antimony are retained strongly in soil and therefore transport into surface water or groundwater is expected to be a minor pathway. The migration pathway of possible concern is considered to be the transport of waterborne metal-rich sediments in storm and river runoff.

The following subsections are fate and transport summaries drawn from the ATSDR *Toxicological Profiles* for lead, (ATSDR, 1999), copper (ATSDR, 2004), and antimony (ATSDR, 1992). ATSDR prepared these profiles from comprehensive reviews of the scientific literature. Specific citations for secondary sources can be found in the subject profiles.

6.1 LEAD

The fate of lead in soil is affected by the specific or exchange adsorption at mineral interfaces, the precipitation of sparingly soluble solid forms of the compound, and the formation of relatively stable organic-metal complexes or chelates with soil organic matter. These processes are dependent on such factors as soil pH, soil type, particle size, organic matter content of soil, the presence of inorganic colloids and iron oxides, cation exchange capacity (CEC), and the amount of lead in soil. The accumulation of lead in most soils is primarily a function of the rate of deposition from the atmosphere. Most lead is retained strongly in soil, and very little is transported into surface water or groundwater. Clays, silts, iron and manganese oxides, and soil organic matter can bind metals electrostatically (cation exchange) as well as chemically (specific adsorption). In soils with pH of 5 and with at least 5% organic matter content, atmospheric lead is retained in the upper 2–5 cm of undisturbed soil. Inorganic lead may be bound into crystalline matrices of rocks and remain essentially immobile; it can also be entrapped in the immobile water surrounding soil macro- and micropores. In soil with a high organic matter content and a pH of 6–8, lead may form insoluble organic lead complexes; if the soil has less organic matter at the same pH, hydrous lead oxide complexes may form or lead may precipitate out with carbonate or phosphate ions. At a pH of 4–6, the organic lead complexes become soluble and leach out or may be taken up by plants (ATSDR, 1999).

The downward movement of elemental lead and inorganic lead compounds from soil to groundwater by leaching is very slow under most natural conditions except for highly acidic situations. The conditions that induce leaching are the presence of lead in soil at concentrations that either approach or exceed the CEC of the soil, the presence of materials in soil that are capable of forming soluble chelates with lead, and a decrease in the pH of the leaching solution (for example, acid rain) (ATSDR, 1999).

6.2 COPPER

Most copper deposited on soil will be adsorbed with greater concentrations of copper measured in the upper 5–10 centimeters of soil in comparison to lower soil depths, except in sandy soils where the lability of bound copper is greater. Copper's movement in soil is determined by a host of physical and chemical interactions of copper with the soil components. In general, copper will adsorb to organic matter, carbonate minerals, clay minerals, or hydrous iron and manganese oxides. Sandy soils with low pH have the greatest potential for leaching. In most temperate soils, the pH, organic matter, concentrations of metal oxyhydroxides and ionic strength of the soil solutions are the key factors affecting adsorption. Soil microorganisms also affect the absorption of copper in soils due to the uptake and assimilation of the metal by these microorganisms. However, it is not known how the rate of uptake and absorption capacity of the microorganisms for copper compares with the binding capacity and affinities of copper by organic matter in soils, such as humic and fulvic acids. When the amount of organic matter is low, the mineral content or Fe, Mn, and Al oxides become important in determining the adsorption of copper. Copper binds strongly to soils with high organic content (14–34% organic matter, dry weight) and the distribution of copper in the soil solution is less affected by changes in pH (within the range of pHs normally encountered in the environment) than other metals are (ATSDR, 2004).

Copper concentrations in drinking water obtained from groundwater can be affected by the leaching of copper from soil. Reservoir sediments have been shown to be sources of copper in drinking water. Although much of the copper is bound to inorganic or organic matrices in soils and sediments, there is the potential for release of copper into pore water within soils and sediments depending on the extractability of the copper and soil conditions. At pHs above 5, absorption of copper from pore water on to soil components becomes a significant process, whereas at pHs below 5, copper largely remains in pore water and is therefore mobile in soil (ATSDR, 2004).

6.3 ANTIMONY

Little is known of the adsorptive behavior of antimony, its compounds, and ions. The binding of antimony to soil is determined by the nature of the soil and the form of antimony deposited on the soil. Some forms of antimony may bind to inorganic and organic ligands. On the other hand, a mineral form would be unavailable for binding. Some studies suggest that antimony is fairly mobile under diverse environmental conditions, while others suggest that it is strongly adsorbed to soil. Because antimony has an anionic character (e.g., Sb(OH)i), it is expected to have little affinity for organic carbon. Antimony is known to form coprecipitates with hydrous iron, manganese, and aluminum oxides in soil and sediment (ATSDR, 1992).

6.4 PROPERTIES AFFECTING TRANSPORT AND MOBILITY

The transport and mobility of both lead and copper increases with low soil or water pH, high amounts of annual precipitation, and the absence of organic compounds in the soil. Similarly, the strength of antimony's adsorption to soil and sediments appears to be dependent upon a variety of factors such as pH, organic matter content, as well as the oxidation state of the particular salt. As noted earlier, some studies indicate that antimony is highly mobile, while others conclude that it strongly adsorbs to soil. In water, it usually adheres to sediments. Soil type (relative percentages of sand-silt-clay and organic materials), topography and the extent of vegetative cover also play a significant role in the transport and mobility of these metals. These factors are further discussed below with respect to the TOAR-FUDS.

Soils within the footprint of the TOAR-FUDS are characterized by the US Soil Conservation Service as stony loams, silty loams, and mucky peat. These soils developed in loamy, glacial deposits derived from shales, siltstones and sandstones and have pH values ranging from 4.5 to 6. The majority of the soils have thick, slowly permeable fragipan subsoils which would tend to inhibit vertical migration of the metals while increasing residence time and therein the probability for electrostatic bonding and adsorption of the metals to soil particles. USGS topographic maps of the TOAR show numerous and extent of wet areas both within and surrounding the study area generally associated with Morris Series and mucky peat (highly organic) soils. Field personnel describe soils encountered during the RI as having a thick root/organic layer which should also enhance bonding and adsorption to soils in the study area. In addition, wet areas are highly vegetated and remaining areas forested further decreasing the potential for movement of sediment to local streams and ponds.

7. RISK EVALUATION

7.1 RISK EVALUATION FOR UNEXPLODED ORDNANCE

An explosive safety risk is the probability for a UXO item to detonate and potentially cause harm as a result of human activities. An explosive safety risk exists if a person can come into contact with a UXO item and act upon it to cause detonation. The potential for an explosive safety risk depends on the presence of three critical elements: a source (presence of UXO), a receptor or person, and interaction between the source and receptor (such as picking up the item or disturbing the item by plowing). There is no explosive safety risk if any one element is missing. Each of the three elements provides a basis for implementing effective risk-management response actions.

The exposure route for a UXO item to a receptor is primarily through direct contact as a result of some human activity. Agricultural or construction activities involving subsurface intrusion are examples of human activities that will increase the likelihood for direct contact with buried UXO. A UXO item will tend to remain in place unless disturbed by human or natural forces, such as erosion or frost heave. Movement of the UXO item may increase the probability for direct human contact, but not necessarily result in a direct contact or exposure.

A qualitative risk evaluation was conducted using the Ordnance and Explosives Risk Impact Assessment (OERIA) Interim Guidance document (USACE 2001) to assess explosive safety risks to the public at the TOAR site. The risk evaluation presented herein is based on the site characterization findings presented in Section 4 for the following UXO source areas, as defined by the CSM:

- Firing points.
- Impact areas.
- Buffer zones.
- Other Areas.

7.1.1 Definition of Risk Evaluation Factors, Categories, and Subcategories

The potential risks posed by UXO are characterized qualitatively by evaluating three primary risk factors. The three primary risk factors include: (1) presence of a UXO source, (2) site characteristics that affect the accessibility or pathway between the source and human receptor, and (3) human factors that define the number of receptors and type of activities that may result in direct contact between a receptor and a UXO source. By performing a qualitative assessment of these three risk factors, an overall assessment of the explosive safety risk posed by UXO is evaluated. The following subsections describe the components of each of the primary risk factors. An overview of the risk evaluation factors for UXO is presented in Figure 7-1. A graphical presentation of the exposure pathways for potential receptors to UXO at the TOAR-FUDS is presented in Figure 7-2.

7.1.1.1 Presence of UXO Factors

There are four categories that are evaluated within the presence of UXO risk factor. These include the UXO type, UXO sensitivity, UXO density, and UXO depth distribution.

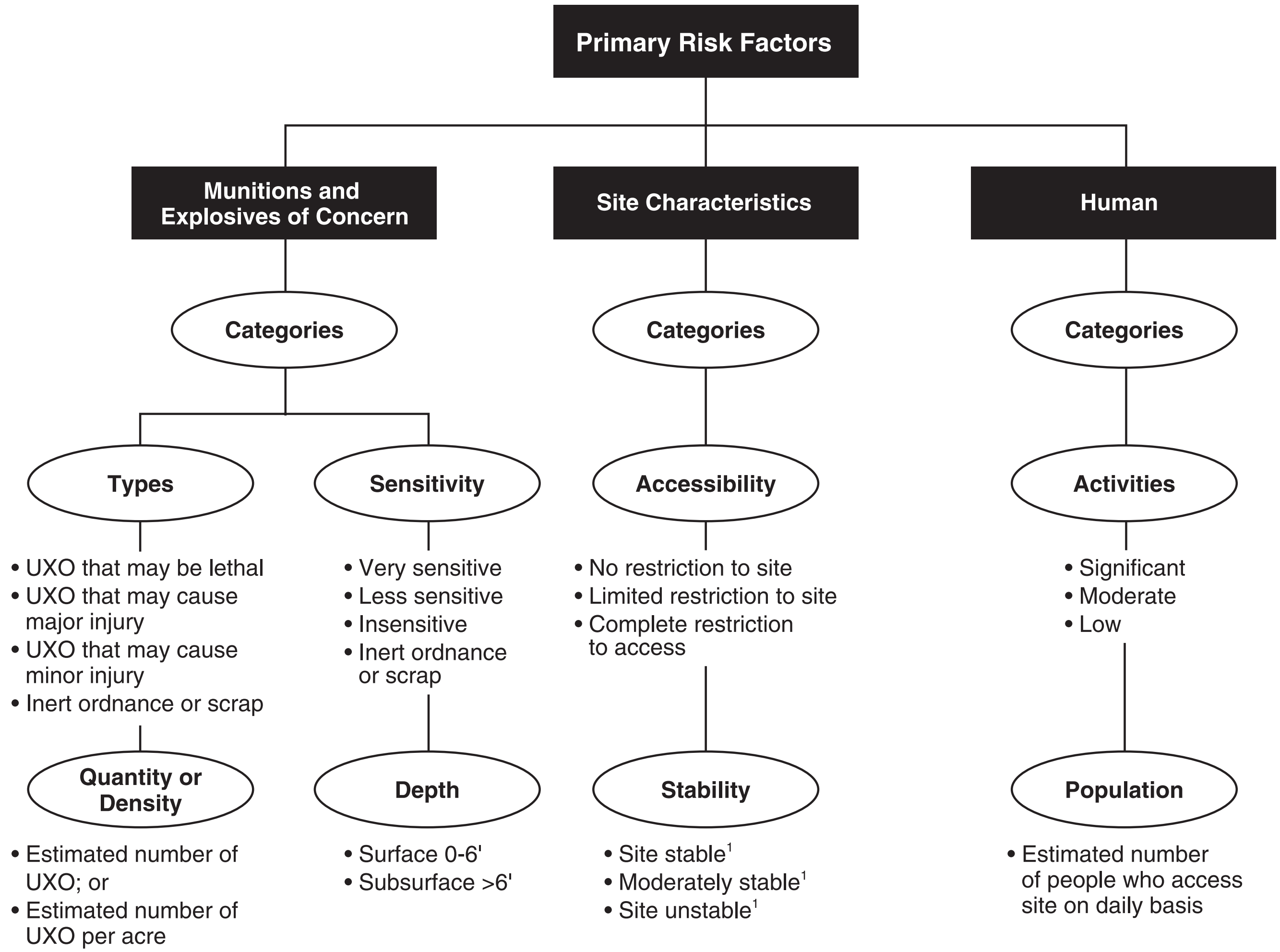
7.1.1.1.1 Type

The UXO type affects the likelihood of injury and the severity of exposure. If multiple UXO items are identified in an area, the item that poses the greatest risk to public health is selected for risk evaluation. There are four subcategories of UXO type, as shown in Table 7-1. These subcategories are presented in order of severity from highest to lowest risk.

Table 7-1 UXO Type Subcategories

Subcategory	UXO Type Description
Most severe	UXO that may be lethal if detonated by an individual's activities.
Moderately severe	UXO that may cause major injury to an individual if detonated by an individual's activities.
Least severe	UXO that may cause minor injury to an individual if detonated by an individual's activities.
No injury	Munitions debris (inert), will cause no injury.

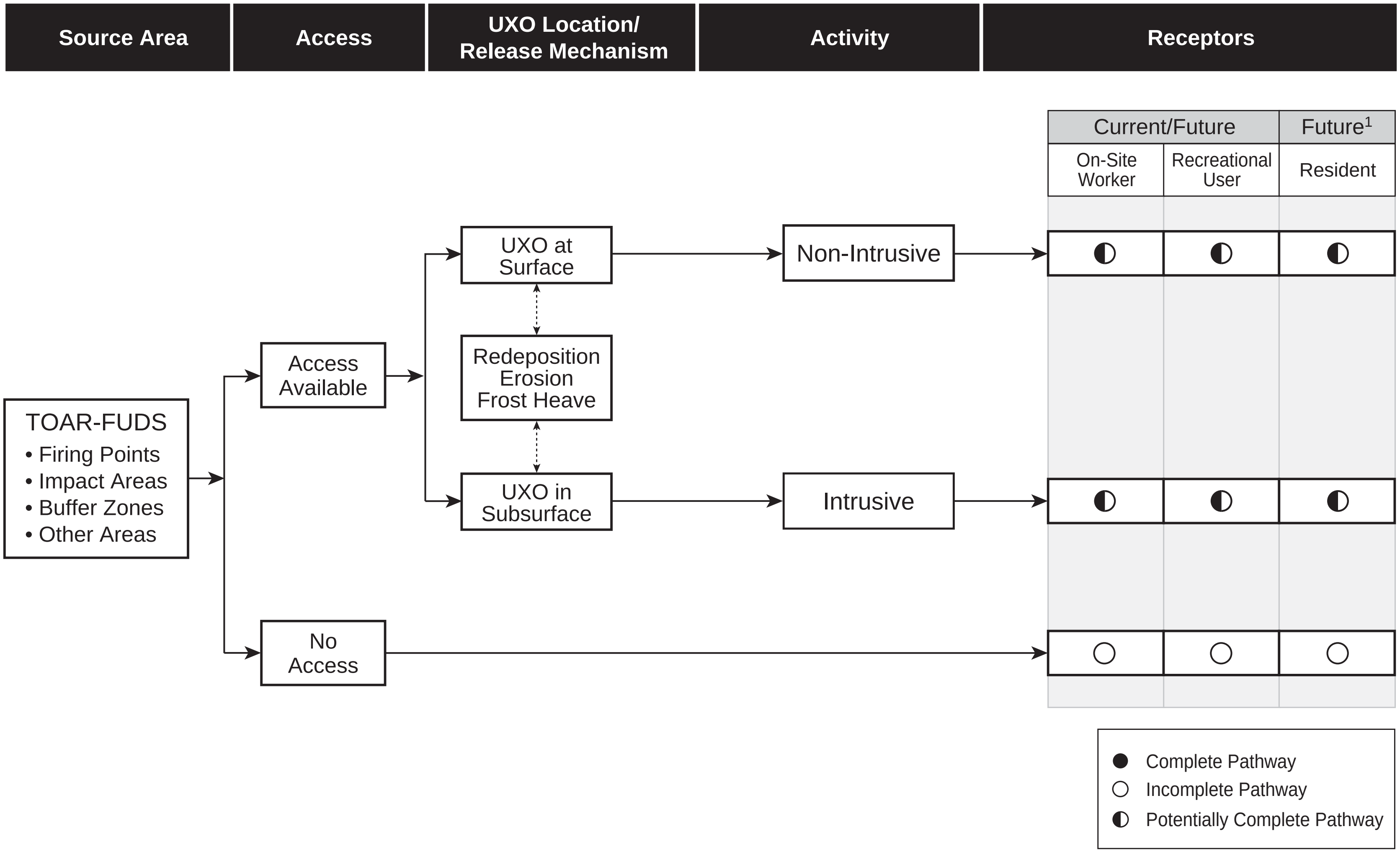
Figure 7-1 UXO Risk Factor Tree



Notes
1. Function of type of activities/use and depth of UXO.
2. Bulleted items are subcategories to each category.

05P-0007

Figure 7-2 UXO Exposure Pathways Analysis for the TOAR-FUDS



[1]The future anticipated land use for the TOAR-FUDS is recreational. Future residents are not anticipated.

05P-0692-1

7.1.1.1.2 Sensitivity

UXO sensitivity affects the likelihood of detonation and the severity of exposure. Factors considered in evaluating sensitivity include fuzing and environmental factors such as weathering. There are four potential subcategories of UXO sensitivity. When multiple subcategories of UXO types are discovered in an area, the highest risk subcategory is used in the risk evaluation. The subcategories of sensitivity are defined and presented in order from highest to lowest in Table 7-2.

Table 7-2 UXO Sensitivity Subcategories

Subcategory	UXO Sensitivity
Very sensitive	UXO that is very sensitive, i.e., electronic fuzing, land mines, booby traps.
Less sensitive	UXO that has standard fuzing.
Insensitive	UXO that may have functioned correctly, or is unfuzed, but has a residual risk.
Inert	Munitions Debris (inert), will cause no injury.

7.1.1.1.3 Density

UXO density affects the likelihood that an individual will be exposed to UXO. There exists a direct relationship between density and potential for harm. For example, the greater the density of UXO (numbers per acre) is, the greater the likelihood of exposure to a UXO is, and thereby, the greater the opportunity to create an incident is.

The UXO density at the TOAR site has been evaluated using a number of factors and methods to account for the multiple lines of evidence available to assess this key characteristic. The UXO density at the TOAR site has been evaluated using the following information:

- The results from the 1998 HFA TCRA conducted in the campground area in Park.
- The results from the 2004 RI, using DGM site characterization findings (UXO item found per acres investigated using DGM).
- The results from the 2004 RI, using IAR site characterization findings (UXO items found and acres investigated using IAR).

- The "Average UXO Density Expected", as calculated by UXO Estimator Module 2.
- The 95% Confidence level density, as calculated by UXO Estimator Module 2.

7.1.1.1.4 Depth Distribution

The UXO depth distribution refers to where the UXO item is located vertically in the subsurface. The UXO depth distribution affects the likelihood that an individual will be exposed to UXO. There exists a direct inverse relationship between the depth at which UXO are found and the likelihood of exposure to the UXO; i.e. the greater the depth where the UXO are found, the lower the risk of exposure. There are three subcategories within the UXO depth distribution category: surface, near-surface, and subsurface. The surface subcategory includes those items recovered from the ground surface to a depth of 6 in. The near-surface subcategory includes those items recovered from 6 to 12 in. bgs. The subsurface subcategory includes those items recovered from greater than 12 inches bgs. Assessment of this risk category reflects the findings of the site characterization.

7.1.1.2 Site Characteristics Factors

There are two categories that are evaluated in the site characteristic risk factor. These are site accessibility and site stability.

7.1.1.2.1 Site Accessibility

The accessibility of an UXO source area affects the likelihood of encountering UXO. Natural or physical barriers can limit the accessibility. Natural barriers can include the terrain or topography of the area; water features such as streams, creeks, lakes and wetland areas; as well as the native vegetation. Physical barriers can include walls and fences that limit the public accessibility to the UXO source area. Both the physical and natural barriers found at a UXO source area are considered when evaluating this category. Site accessibility has three subcategories. These subcategories are presented in Table 7-3.

Table 7-3 Site Accessibility Subcategories

Subcategory	Accessibility Description
No restriction to site	No manmade barriers, gently sloping terrain, no vegetation that restricts access, no water that restricts access.
Limited restriction to access	Manmade barriers; vegetation that restricts access; water, snow, or ice cover; and/or terrain restricts access.
Complete restriction to access	All points of entry are controlled.

It should be recognized that significant portions of both the Park and Game areas of the TOAR-FUDS consist of lakes, streams, ponds, and wetland areas that are continually submerged, and adjacent areas that are intermittently submerged depending on precipitation amounts and intensities. The land areas that are covered with water features (lakes, streams, ponds, and wetlands) are estimated at twenty five percent (25%) of the total land area of the TOAR-FUDS. This 25% submerged land area was estimated using aerial photography and GIS tools. The accessibility factor inherent to the receptor pathway to UXO items that are located within a water feature is significantly lower than if the UXO items were located on solid ground.

7.1.1.2.2 Site Stability

This category relates to the probability of being exposed to UXO by natural processes. These natural processes include recurring natural events (e.g., frost heave, sand movement, erosion) or extreme natural events (e.g., tornadoes, hurricanes). The local soil type, topography, climate, and vegetation affect the stability of the site. The soil type and climate primarily affect the depth of penetration of the UXO. Over time, the soil type and climate will also affect the degree of erosion that takes place at a site. Topography and vegetation will also affect the rate of erosion that takes place in an area. Site stability has three subcategories. Table 7-4 describes these subcategories.

Table 7-4 Site Stability Subcategories

Subcategory	Stability Description
Site stable	UXO should not be exposed by natural events.
Moderately stable site	UXO may be exposed by natural events.
Site unstable	UXO most likely will be exposed by natural events.

7.1.1.3 Human Factors

There are two categories that are evaluated in the primary human risk factor. These include activities and population.

7.1.1.3.1 Site Activity

The types of activities conducted at a site affect the likelihood of encountering UXO. The types of activities may be generally classified as recreational and occupational. This category examines whether the impact from an activity on UXO is significant, moderate, or low. In order to assign such a score, the general guidelines presented in Table 7-5 were considered. First, the type of activity should be identified. Then, the depth of the activity must also be considered. For example, at a site where UXO is at the surface, all activities that can impact UXO at the surface are considered activities that have significant impact. Conversely, if all UXO is located at depths greater than 1 ft and only surface impact activities are being performed, then the activities are considered as moderate or low impact. After the type of activity and depth of UXO are identified, then a score of significant, moderate or low may be assigned.

Table 7-5 Activities and UXO Contact Probability Levels

Examples of Activities	Actual Depth of UXO (inches)	Contact Level
Child play, trespassing, hunting, fishing, hiking, swimming, jogging, ranching, surveying, off-road driving	0-6 6-12 >12	Significant Low Low
Picnic, camping, metal detecting	0-6 6-12 >12	Significant Moderate Low
Construction, timber harvesting, crop farming	0-6 6-12 >12	Significant Significant Moderate

7.1.1.3.2 Population

This category refers to the number of people that potentially access the UXO source area on a daily basis. The number of people using the UXO source area affects the likelihood of encountering UXO. A direct relationship exists between the number of people and the risk of exposure. An estimate of the number of people accessing the UXO source area in Park on a daily basis was made using attendance information obtained from the DCNR. An estimate of the number of people accessing the UXO source area in Game on a daily basis was made using best professional judgment based on knowledge of the land use and site accessibility.

7.1.2 Risk Evaluation

Each of the primary risk factors identified above was evaluated using the data collected from the RI/FS field investigation. The risk evaluation for each UXO source area is presented in Table 7-6. The following subsections discuss the risk evaluation by each primary risk factor.

7.1.2.1 Presence of UXO Factors

7.1.2.1.1 UXO Type

The UXO type affects the likelihood of injury and the severity of exposure and is summarized for each UXO source area in the following paragraphs.

Table 7-6 UXO Risk Evaluation

Area	Ordnance and Explosives Factors					Site Characteristics Factors		Human Factors	
	Type[1]	Injury Threat	Sensitivity	Average UXO Density Expected[2]	Number of UXO Recovered by Depth[3]	Accessibility	Stability	Activities	Population[4]
Firing Points Game	None recovered (potential for 155-mm projectile)	No known injury threat (potential for Most Severe)	No known sensitivity (potential for Less Sensitive)	None Expected[5]	No UXO, DMM, or MD recovered	No Restriction	Moderately sable	Moderate (hunting, hiking, timber harvest)	10 – 100
Firing Points Park	None recovered (potential for 155-mm projectile)	No known injury threat (potential for Most Severe)	No known sensitivity (potential for Less Sensitive)	None Expected[5]	No UXO, DMM, or MD recovered	No restriction	Moderately stable	Low (hiking, camping) to Potentially Significant (construction)	18 – 365 (133)
Impact Area Game	155-mm projectile	Most severe	Less sensitive	0.57 – 1.5	Surface – 26 Near surface – 6 Subsurface – 3	Limited restriction	Moderately stable	Significant (hunting, hiking, timber harvest)	10 – 100
Impact Area Park	155-mm projectile	Most severe	Less sensitive	0.29 – 2.5	Surface – 32 Near surface – 5 Subsurface –1	Limited restriction	Moderately stable	Significant (hiking, camping, construction)	18 – 365 (133)
Buffer Zone Game	155-mm projectile	Most severe	Less sensitive	0.055 – 0.33	Surface – 2 Near surface – 1 Subsurface – 0	Limited restriction	Moderately stable	Significant (hunting, hiking, timber harvest)	10 – 100
Buffer Zone Park	Munitions debris (potential for 155-mm projectile)	No known injury threat (potential for Most Severe)	Inert (potential for Less Sensitive)	0.018 – 0.11	No UXO or DMM recovered, MD recovered	Limited restriction	Moderately stable	Low (hiking, camping) to Potentially Significant (construction)	18 – 365 (133)
Lake Watawga Area	155-mm projectile	Most severe	Less sensitive	0.072	Surface – 2 Near surface – 0 Subsurface – 0	Limited restriction	Moderately stable	Significant (hiking, camping)	18 – 365 (133)
Other Areas Game	Munitions debris (potential for 155-mm projectile)	No known injury threat (potential for Most Severe)	Inert (potential for Less Sensitive)	None Expected[6]	No UXO or DMM recovered, MD recovered	Limited restriction	Moderately stable	Moderate (hunting, hiking, timber harvest)	10 – 100
Other Areas Park	Munitions debris (potential for 155-mm projectile)	No known injury threat (potential for Most Severe)	Inert (potential for Less Sensitive)	None Expected[6]	No UXO, DMM or MD recovered	Limited restriction	Moderately stable	Low (hiking, camping) to Potentially Significant (construction)	18 – 365 (133)

[1] Denotes the item that poses the greatest risk to the public based on findings during the RI/FS as described in Section 4.
[2] Denotes the Average UXO Density Expected calculated using UXO Estimator Module 2, based on site characterization findings based on IAR and DGM results, respectively, as presented in Table 4-27.
[3] Denotes number of UXO found at the surface (0 to 6 inches deep), near-surface (6 to 12 inches bgs), and in the subsurface (>12 inches deep) during the 2004 RI.
[4] Population estimates for Park areas were provided by the DCNR. Values shown are minimum and maximum average daily attendance obtained from monthly data for 2004, with total annual average daily attendance shown in parentheses. Population estimates for Game areas were not available. Values shown are estimated annual minimum and maximum daily average attendance.
[5] The Average UXO Density Expected has been designated as "None Expected" based on guidance provided by CEHNC MM-CX since no DMM were found, and no UXO or MD recovered can be associated with the Firing Points. The Average UXO Density Expected was not calculated in UXO Estimator Module 2 for Firing Points.
[6] The Average UXO Density Expected has been designated as "None Expected" based on guidance provided by CEHNC MM-CX since the Other Areas are outside the expected areas of MEC contamination. The Average UXO Density Expected calculated by UXO Estimator Module 2 for IAR and DGM results in Other Areas Game and Other Areas Park are 0.029 – 0.073 and 0.020 – 0.11, respectively.

Firing Points - Game: No UXO (or DMM) items were located during the site characterization efforts that could be associated with the FPs – Game MEC source areas. The items recovered during the RI/FS site characterization field efforts are classified as inert and pose no explosive safety risk. No prior finds of UXO (or DMM) items within this area have been reported for FPs - Game areas.

Firing Points - Park: No UXO (or DMM) items were located during the site characterization efforts that could be associated with the FPs – Park MEC source areas. The items recovered during the RI/FS site characterization field efforts are classified as inert and pose no explosive safety risk. No prior finds of UXO (or DMM) items within this area have been reported for FPs – Park areas.

Impact Areas - Game: Numerous fuzed HE-filled projectiles, including 75-mm and 155-mm rounds, were identified at the IAs – Game UXO source areas during the RI/FS. Additionally, shrapnel projectile rounds, including 75-mm and 155-mm, and one 81-mm mortar round, were recovered during site characterization field efforts. A total of 35 UXO were recovered from the IAs – Game UXO source areas during the 2004 RI. Approximately 74% of the recovered UXO were located in the surface depth range of 0 to 6 in. bgs. The 155-mm HE projectile poses the greatest explosive safety risk to the public and is classified in the "most severe" subcategory. The 155-mm HE projectile was carried forward for this risk assessment.

Impact Areas - Park: Numerous fuzed HE-filled projectiles, including 37-mm, 75-mm, and 155-mm rounds, were identified at the IAs – Park UXO source areas during the RI/FS. Additionally, numerous shrapnel projectiles, including 75-mm and 155-mm rounds, were recovered during site characterization field efforts. A total of 38 UXO were recovered from the IAs – Park UXO source areas during the 2004 RI. Approximately 84% of the recovered UXO were located in the surface depth range of 0 to 6 in. bgs. The 155-mm HE projectile poses the greatest explosive safety risk to the public and is classified in the "most severe" subcategory. The 155-mm HE projectile was carried forward for this risk assessment. Additionally, three UXO were recovered from this area during the 2004 WESTON Site Visit. Additionally, a total of 273 UXO items were recovered during the 1998 TCRA conducted by HFA in the camping area located north of Tobyhanna Lake, within the IA – Park UXO Source Area.

Buffer Zone - Game: A total of three UXO were recovered from the BZ-Game UXO source area during the RI/FS site characterization field efforts. Two 155-mm HE projectiles and one 75-mm shrapnel round were recovered during the 2004 RI. Approximately 67% of the recovered UXO were located in the surface depth range of 0 to 6 in. bgs. Additionally, one 155-mm shrapnel round was recovered during the 2004 TCRA from the trails within BZ – Game UXO source area. The 155-mm HE projectile poses the greatest explosive safety risk to the public and is classified in the "most severe" subcategory. The 155-mm HE projectile was carried forward for this risk assessment.

Buffer Zone - Park: No UXO were recovered from the BZ-Park UXO source area during the RI/FS site characterization field efforts. The items recovered during the RI/FS site characterization field efforts are classified as inert and pose no explosive safety risk. However, five (5) UXO items were recovered during the 1998 HFA TCRA along the trails located within the BZ – Park UXO source area.

Lake Watawga Area: The Lake Watawga Area is a subdivided portion of the BZ-Park UXO source area that has been delineated as a separate area for risk characterization purposes based on the localized presence of UXO adjacent to the northern FUDS property boundary and residential housing development north of this boundary. Two UXO were recovered from the Lake Watawga area UXO source areas during the RI/FS site characterization field efforts. The recovered items were 155-mm and 75-mm HE-filled projectiles. Of the recovered UXO, 100% were located in the surface depth range of 0 to 6 inch bgs. Additionally, two UXO items were recovered by CENAB personnel during a 2004 site visit in the Lake Watawga UXO source area. The 155-mm HE projectile poses the greatest explosive safety risk to the public and is classified in the "most severe" subcategory. The 155-mm HE projectile was carried forward for this risk assessment.

Other Areas - Game: No UXO were located during the site characterization efforts conducted on the Other Areas – Game UXO source areas. The items recovered during the RI/FS site characterization field efforts are classified as inert and pose no explosive safety risk. No prior finds of UXO within this area have been reported for Other Areas – Game.

Other Areas - Park: No UXO were located during the site characterization efforts conducted on the Other Areas – Park UXO source areas. The items recovered during the RI/FS site characterization field efforts are classified as inert and pose no explosive safety risk. No prior finds of UXO within this area have been reported for Other Areas – Park.

7.1.2.1.2 UXO Sensitivity

The subcategory of "less sensitive" (standard fuzing) is assigned to the UXO sensitivity category for the IA – Game, IA – Park, BZ – Game, BZ – Park, and Lake Watawga area UXO source areas, as defined in Table 7-2. The UXO sensitivity for the FP – Game, FP – Park, Other Areas – Game, and Other Areas – Park UXO source areas are categorized as "inert," because zero UXO (or DMM) were recovered from these areas during the RI/FS field work nor have been reported from prior field work within these areas. Although zero UXO (or DMM) were recovered in these areas, the sensitivity of potential UXO in these areas is expected to be the same as the sensitivity of UXO recovered in the areas of the TOAR-FUDS described above, with most items falling into the subcategory of "less sensitive" (standard fuzing).

7.1.2.1.3 UXO Density

The UXO density at the TOAR site has been evaluated using a number of factors and methods to account for the multiple lines of evidence available to assess this key characteristic. The UXO density at the TOAR site has been evaluated using the following information:

- The results from the 1998 HFA TCRA conducted in the campground in Park (Impact Area).
- The results from the 2004 RI, using DGM site characterization findings (UXO item found per acres investigated using DGM).
- The results from the 2004 RI, using IAR site characterization findings (UXO items found and acres investigated using IAR).
- The "Average UXO Density Expected", as calculated by UXO Estimator Module 2.
- The 95% Confidence level density, as calculated by UXO Estimator Module 2.

The multiple lines of evidence available for evaluating UXO density provided a range of values for this key factor for each of the UXO source area site types investigated at the TOAR-FUDS. It should be noted that although there is a range of values derived from these different lines of evidence, the range of UXO density values are internally consistent within each UXO source area. The "Average UXO Density Expected" value, as calculated by UXO Estimator Module 2, was used as the UXO density value for the qualitative UXO risk evaluation. UXO densities calculated based on the data from the 2004 RI, including UXO densities calculated by UXO Estimator Module 2, are presented in Tables 4-26 and 4-27, and is summarized for each UXO source area in the following paragraphs.

FP – Game and FP – Park: The UXO densities for both of the FP MEC source areas are calculated as "not applicable" because no UXO (or DMM) were recovered that could be associated with FPs at the TOAR-FUDS.

IA – Game: A total of 35 UXO have been recovered during all investigations, both on the surface and subsurface, in the IAs in the Game portion of the TOAR-FUDS site. The Average UXO Density Expected in the IA – Game UXO source areas is calculated by UXO Estimator Module 2 as 0.57 to 1.5 UXO per acre based on the results of the RI using IAR and DGM data. This Average UXO Density Expected calculated range of UXO density values agrees with the actual density range as calculated by the number of UXO items recovered per acre of land area investigated in the IA – Game source area, which is 0.51 to 1.4 UXO per acre. The remaining lines of evidence available result in UXO density values ranging from 0.91 to 2.0 UXO items per acre for the IA – Game UXO source area.

IA – Park: A total of 314 UXO have been recovered during all investigations, both on the surface and subsurface, in the IAs in the Park portion of the TOAR-FUDS. The Average UXO Density Expected in the IA – Park UXO source areas is calculated by UXO Estimator Module 2 as 0.29 to 2.5 UXO per acre based on the results of the RI using IAR and DGM data. This Average UXO Density Expected calculated range of UXO density values agrees with the actual density range as calculated by the number of UXO items recovered per acre of land area investigated at the IA – Park source area, which is 0.25 to 2.4 UXO per acre. The remaining lines of evidence available result in UXO density values ranging from 0.47 to 3.2 UXO items per acre for the IA – Park UXO source area.

BZ – Game: A total of four UXO have been recovered during all investigations, both on the surface and subsurface, in the BZ – Game portion of the TOAR-FUDS. The Average UXO Density Expected in the BZ – Game UXO source areas is calculated by UXO Estimator Module

2 as 0.055 to 0.33 UXO per acre based on the results of the RI using IAR and DGM data. This Average UXO Density Expected calculated range of UXO density values agrees with the actual density range as calculated by the number of UXO items recovered per acre of land area investigated in the BZ – Game source area, which is 0.028 to 0.22 UXO per acre. The remaining lines of evidence available result in UXO density values ranging from 0.13 to 0.70 UXO items per acre for the BZ – Game UXO source area. Also, in general, UXO and MD recovered in BZ – Game at the TOAR-FUDS have been recovered in the vicinity of IAs. This is indicative of the fact that UXO density in BZs is expected to vary based on proximity to IAs.

BZ – Park: A total of five UXO have been recovered during previous investigations, both on the surface and subsurface, in the BZ – Park portions of the TOAR-FUDS. No UXO was recovered during the RI. The Average UXO Density Expected in the BZ – Park UXO source areas is calculated by UXO Estimator Module 2 as 0.018 to 0.11 UXO per acre based on the results of the RI using IAR and DGM data. This Average UXO Density Expected calculated range of UXO density values agrees with the actual density range as calculated by the number of UXO items recovered per acre of land area investigated in the BZ – Park source area, which is 0.0 UXO per acre, based on no recovered UXO items. The remaining lines of evidence available result in UXO density values ranging from 0.054 to 0.34 UXO items per acre for the BZ – Park UXO source area. Also, in general, UXO recovered previously in BZ – Park at the TOAR-FUDS have been recovered in the vicinity of IAs. This is indicative of the fact that UXO density in BZs is expected to vary based on proximity to IAs.

Lake Watawga Area: A total of four UXO have been recovered during all investigations, both on the surface and subsurface, in the Lake Watawga area. The Average UXO Density Expected in the Lake Watawga Area is calculated by UXO Estimator Module 2 as 0.072 UXO per acre based on the results of the RI using IAR data. It should be noted that only a minimal land area was investigated due to safety concerns with intrusively investigating selected anomalies in areas located within the fragmentation distance of adjacent residential housing development. The remaining lines of evidence available result in a UXO density value of up to 0.15 UXO items per acre for the Lake Watawga UXO source area. Two additional UXO items were recovered during the 2004 CENAB site visit. The Lake Watawga area is suspected to contain numerous UXO based on its location adjacent to, and immediately downrange of, the IA – Park UXO Source area.

Other Areas – Game: No UXO have been recovered at the Other Areas – Game portion of the TOAR-FUDS. The Average UXO Density Expected in the Other Areas – Game UXO source areas is calculated by UXO Estimator Module 2 as 0.029 to 0.073 UXO per acre based on the results of the RI using IAR and DGM data. This Average UXO Density Expected calculated range of UXO density values agrees with the actual density range as calculated by the number of UXO items recovered per acre of land area investigated in the Other Areas – Game UXO source area, which is 0.0 UXO per acre, based on no recovered UXO items. The remaining lines of evidence available result in UXO density values ranging from 0.087 to 0.22 UXO items per acre for the Other Areas – Game UXO source area.

Other Areas – Park: No UXO have been recovered at the Other Areas – Park portion of the TOAR-FUDS. The Average UXO Density Expected in the Other Areas – Park UXO source areas is calculated by UXO Estimator Module 2 as 0.020 to 0.11 UXO per acre based on the results of the RI using IAR and DGM data. This Average UXO Density Expected calculated range of UXO density values agrees with the actual density range as calculated by the number of UXO items recovered per acre of land area investigated at the Other Areas – Park UXO source area, which is 0.0 UXO per acre, based on no recovered UXO items. The remaining lines of evidence available result in UXO density values ranging from 0.060 to 0.33 UXO items per acre for the Other Areas – Park UXO source area.

7.1.2.1.4 UXO Depth Distribution

The UXO depth distribution affects the likelihood that an individual will be exposed to UXO. There is a direct relationship between the depth at which UXO are found and the likelihood of exposure to the UXO. There are three subcategories within the distribution depth category: surface (0 to 6 in. bgs); near-surface (6 to 12 in. bgs); and, subsurface (> 12 in. bgs). The depth distribution of recovered UXO during the RI across the IA – Game, IA – Park, Lake Watawga area and BZ – Game source areas is:

- Surface (0 to 6 in. bgs) = 80% of total UXO recovered.

- Near Surface (6 to 12 in. bgs) = 15% of total UXO recovered.
- Subsurface (> 12 in. bgs) = 5% of total UXO recovered.

Note that the depth distribution across the TOAR-FUDS for UXO recovered during the RI very nearly matches the depth distribution for UXO recovered during the 1998 HFA TCRA in Park, which was as follows:

- Surface (0 to 6 in. bgs) = 83% of total "live OE" (UXO) recovered.
- Near Surface (6 to 12 in. bgs) = 16% of total "live OE" (UXO) recovered.
- Subsurface (> 12 in. bgs) = 1% of total "live OE" (UXO) recovered.

Also note that zero UXO (or DMM) were recovered during the RI from FPs – Game, FPs – Park, BZ – Park, Other Areas – Game, and Other Areas – Park portions of the TOAR-FUDS. Although zero UXO (or DMM) were recovered in these areas, the depth distribution of potential UXO in these areas is expected to be the same as the depth distribution of UXO recovered in the areas of the TOAR-FUDS described above, with most items within 6 in. of the ground surface.

7.1.2.2 Site Characteristics Factors

7.1.2.2.1 Site Accessibility

The Park portion of the TOAR-FUDS is open to the public for hiking, camping, and recreational activities. The Game portion of the TOAR-FUDS is also open to the public and is used for hiking, hunting, and timber harvesting activities. The accessibility to enter the TOAR-FUDS is unrestricted and major portions of the site are accessible by road and foot. However, large portions of the area consist of moderately steep terrain, are undeveloped, and are heavily forested. The presence of trails provides pedestrian access to interior portions of the site, although the lack of improved roads limits vehicle access into much of the site. Additionally, approximately 25% of the TOAR-FUDS is covered by water features, including lakes, streams, ponds, and wetlands. As such, the site accessibility factor in these areas is evaluated to be limited accessibility.

7.1.2.2.2 Site Stability

Overall, the site stability subcategory is moderately stable for the entire TOAR-FUDS. The location of the TOAR-FUDS makes it probable that UXO will become exposed through natural processes, such as frost heave (or frost jacking) and erosion. According to an article published by the U.S. Army Engineering Research and Development Center, titled "Field Tests of Frost Jacking of Unexploded Ordnance" (Henry, 2005), jacking of ordnance occurs in regions of seasonal freezing when the ordnance is buried in frost-susceptible soil. Frost jacking is a potential transport mechanism for UXO at the TOAR-FUDS because extreme frost depths can reach up to 40 inches in northeastern PA (WESTON, 2004a), and no UXO have been recovered at the site deeper than 22 inches bgs. UXO recovered at the TOAR-FUDS as deep as 40 inches bgs have the potential to migrate to the surface due to frost heave. Erosion is a potential transport mechanism at the TOAR-FUDS because soil cover and relief vary significantly across the site, and thunderstorms can cause local flooding during the summer months, which could expose buried UXO. Also, any future construction activities in Park or Game could allow for migration or movement of UXO.

7.1.2.3 Human Factors

7.1.2.3.1 Site Activities

The type of activities conducted at the TOAR-FUDS, in combination with the depth distribution of UXO, is related to the likelihood of individuals encountering UXO and is critical in determining an appropriate depth for any UXO clearance. Table 7-6 describes the type of activity anticipated in each UXO source area based on the current land use. The future land use is likely to remain unchanged as is discussed in Section 2. The entire TOAR-FUDS site is a wildlife preserve/parkland. The most common site activities are hiking and camping in the Park portion; and hiking, hunting, and timber harvesting within the Game portion. However, significant upgrades to infrastructure in the Park are planned for 2006. Therefore, potential future construction activities in Park should be considered when evaluating site activities, as shown in Table 7-6. Minimal activity which could result in individuals encountering UXO is expected in the wet areas at the TOAR-FUDS.

The confirmed presence of UXO on the surface and near-surface, in combination with the usage of the TOAR-FUDS site for recreational activities in the IA – Park portion of the site results in an overall significant contact level rating. The confirmed presence of UXO on the surface and near-surface, in combination with the usage of the TOAR-FUDS site for recreational, hunting, and timber harvesting activities in the IA – Park portion of the site, results in an overall significant contact level rating. The confirmed presence of UXO on the surface, in combination with the usage of the TOAR-FUDS site for recreational activities in the Lake Watawga area portion of the site, with adjacent residential housing development in the area, results in an overall significant contact level rating. Additionally, the confirmed presence of UXO on the surface and near-surface, in combination with the usage of the TOAR-FUDS site for recreational, hunting, and timber harvesting activities in the BZ – Game portion of the site, results in an overall significant contact level rating.

Alternatively, the lack of recovered UXO (or DMM) at the FPs – Game, FPs – Park, and in Other Areas – Game, Other Areas – Park, and the BZ – Park portions of the TOAR-FUDS result in overall low contact ratings despite their use for recreation and hunting activities.

7.1.2.3.2 Population

There is a single residence for the Park Manager and their family, and it is inhabited on a regular basis. Average daily population information was available for the Park from the DCNR, and is summarized in Table 7-6. No daily visitor information was available for Game because the accessibility to the TOAR-FUDS site is unrestricted. The number of individuals engaged in recreational activities in Game was estimated to range from 10 to 100 individuals per day, depending on the season.

A number of improved trails cross the TOAR-FUDS and allow for pedestrian access to portions of the UXO source areas, including the IAs on both the Game and Park portions of the site. A number of improved roadways, including State Highways 423 and 611, cross portions of the FPs, BZs and Other Areas on the TOAR-FUDS. Additionally, a Conrail passenger train track crosses the central portion of the TOAR-FUDS in a north-south direction. Although the rail transportation corridor allows a relatively high number of people to cross the TOAR-FUDS on a regular basis, it is believed this factor contributes very little to the human factors exposure ratings due to the absence of receptor interaction with the land. However, there is nothing to impede the vehicular traffic occupants from stopping and interacting with lands adjacent to the improved roadways. Receptor population in wet areas at the TOAR-FUDS is expected to be minimal.

7.1.3 Explosive Safety Assessment Summary

The potential risk to public safety associated with the presence of UXO at the TOAR-FUDS was evaluated for UXO source areas, including FPs, IAs, BZs, the Lake Watawga Area, and Other Areas. The results are summarized in Table 7-7 and discussed in the following paragraphs. The explosive safety risk was derived from a combination of the primary risk factors presented above.

Table 7-7 UXO Risk Summary

UXO Source Area	UXO Explosive Hazard
Firing Point – Game	Low
Firing Point – Park	Low
Impact Area – Game	High
Impact Area – Park	High
Buffer Area – Game	Low-Moderate
Buffer Area – Park	Low-Moderate
Lake Watawga Area	High
Other Area – Game	Low
Other Area – Park	Low

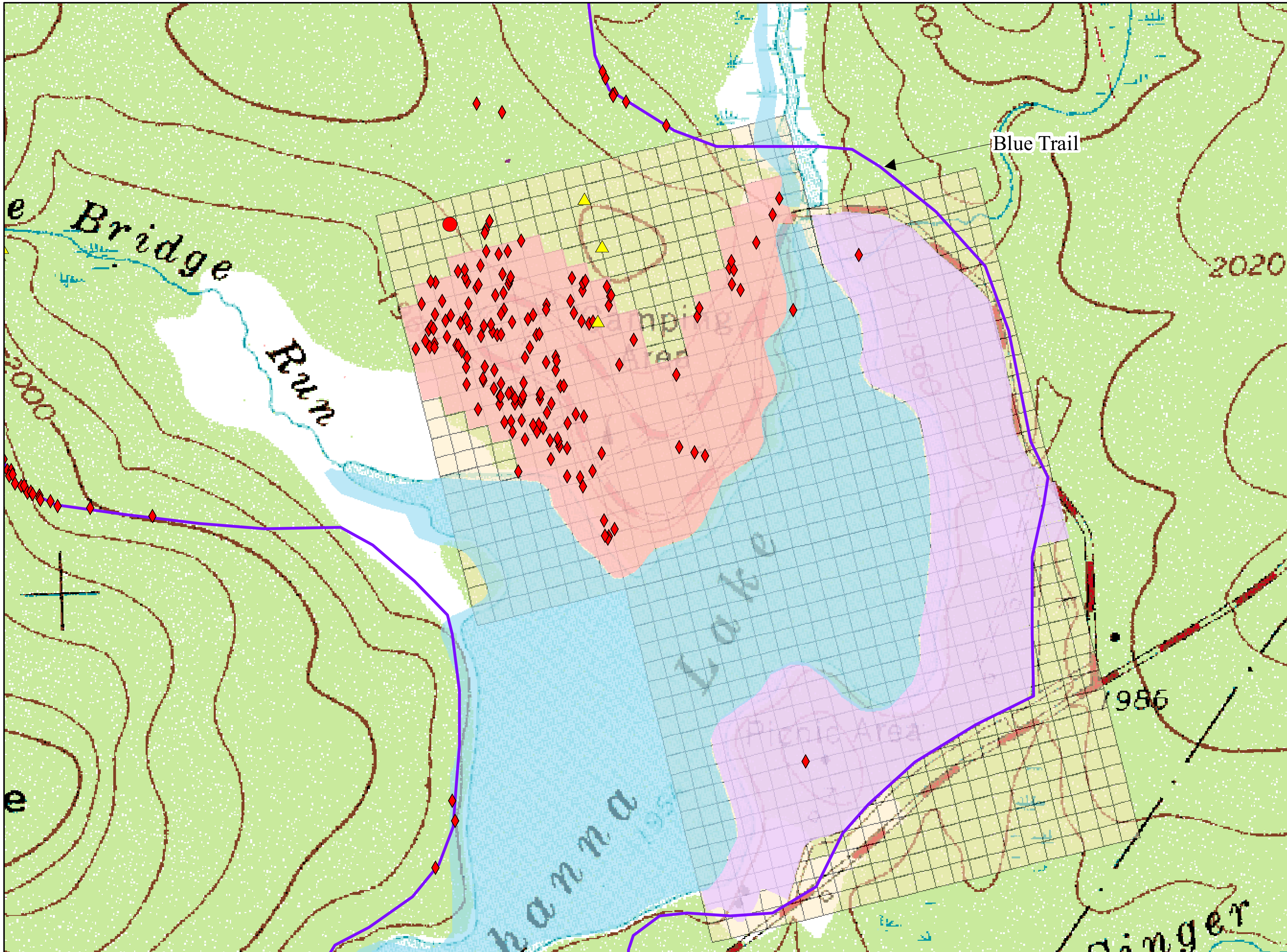
Several TCRAs have previously been conducted on the portions of the TOAR-FUDS roads and trails. However, large portions of the IA UXO source areas have not been cleared. In those areas where a clearance action has been completed, a residual risk still remains because of limitations in UXO detection technology, and the original clearance actions conducted by HFA during the 1998 TCRA were not completed to depth.

FP – Game and FP – Park: No UXO (or DMM) have been identified at the FPs in both the Game and Park portions of the TOAR-FUDS. The UXO density for both of the FP MEC source areas was not applicable due to the lack of recovered UXO. The items recovered from the FPs were not MEC-related items and pose no explosive safety risk. Although no UXO were recovered at FPs during the RI, since 37-mm, 75-mm, and 155-mm UXO items and MD were recovered in IAs and BZs downrange of FPs at the TOAR-FUDS, their potential presence at FPs, while low, cannot be ruled out. These UXO, if present, could be lethal if detonated by an individual's activities. A number of visitors and hunters, estimated at 18 to 365 individuals per day in Park, and 10 to 100 individuals per day in Game, have the potential to come into contact with, and interact with, the land areas at the FPs. <u>Overall, the explosive hazard risk in the FPs at the TOAR-FUDS is evaluated to be low.</u>

IA – Game: A total of 35 UXO have been recovered both on the surface and subsurface at the IAs in the Game portion of the TOAR-FUDS site. The Average UXO Density Expected, as calculated by UXO Estimator Module 2, based on the results of the RI using IAR and DGM data, are calculated to range from 0.57 to 1.47 per acre for the IA – Game portion of the TOAR-FUDS. These UXO could be lethal if detonated by an individual's activities. A number of visitors and hunters, estimated at 18 to 365 individuals per day in Park, and 10 to 100 individuals per day in Game, have the potential to come into contact with, and interact with, UXO located on the ground surface and near-surface. <u>Overall, the explosive hazard risk in the IA – Game at the TOAR-FUDS is evaluated to be high.</u>

IA – Park: A total of 314 UXO have been recovered during all investigations, both on the surface and subsurface, at the IAs in the Park portion of the TOAR-FUDS. The Average UXO Density Expected, as calculated by UXO Estimator Module 2, based on the results of the RI using IAR and DGM data, are calculated to range from 0.29 to 2.5 UXO per acre for the IA – Park portion of the TOAR-FUDS. It should be noted that 278 UXO items were removed and disposed of from the area shown in Figure 7-3 during the 1998 HFA TCRA in Park. The TCRA cleared the area shown down to a maximum depth of 2 feet. Most of the items found in Park, including all 37-mm items, were found within 12 inches of the ground surface. However, the following factors must be considered:

- Prior clearance efforts were bounded to a specific area and did not remove all UXO within the IA – Park boundary. This is evidenced by the fact that UXO and MD were found during the RI in close proximity to the cleared areas.



Legend

- HFA Clearance Area in Campground
- HFA Clearance Area Expanded Search
- HFA Grids

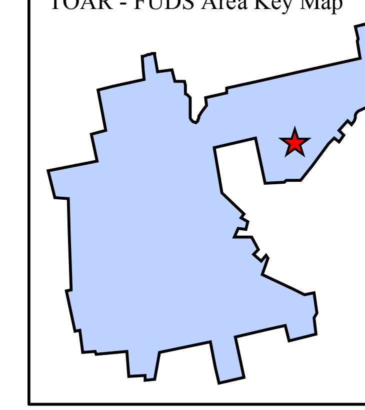
Anomaly Type

- UXO - WESTON RI
- UXO - HFA TCRA
- MD - WESTON RI
- MD - WESTON RI (EMPTY PROJECTILE)

NOTE:
UXO recovered outside clearance areas shown were investigated as part of trails.

SOURCE:
Human Factors Application (HFA),1998.

TOAR - FUDS Area Key Map



0 200 400 800 Feet

Figure 7-3
1998 HFA TCRA in Park

T/TobyhannaUXO/mxd/DRAFT_RIFS/DRAFT_MARCH/HFA_Clearance_Area_7-3.mxd 062705

- UXO items were found at the TOAR-FUDS during the RI at depths greater than 2 feet, and UXO present at depths greater than 2 feet in the area cleared could move toward the surface due to frost heave or erosion.

These UXO could be lethal if detonated by an individual's activities. A number of visitors and hunters, estimated at 18 to 365 individuals per day in Park, and 10 to 100 individuals per day in Game, have the potential to come into contact with, and interact with, UXO located on the ground surface and near-surface. Based on the factors listed above, and based on existing site accessibility, site activity, and population, the explosive hazard risk in the IA – Park remains high.

BZ – Game: A total of four UXO have been recovered during all investigations, both on the surface and subsurface, in the BZ – Game portion of the TOAR-FUDS. The Average UXO Density Expected, as calculated by UXO Estimator Module 2, based on the results of the RI using IAR and DGM data, are calculated to range from 0.055 to 0.33 UXO per acre for the BZ – Game Areas of the TOAR-FUDS. Also, in general, UXO and MD recovered in BZ – Game at the TOAR-FUDS have been recovered in the vicinity of IAs. This is indicative of the fact that UXO density in BZs is expected to vary based on proximity to IAs. These UXO could be lethal if detonated by an individual's activities. A number of visitors and hunters, estimated at 10 to 100 individuals per day, have the potential to come into contact with, and interact with, UXO located on the ground surface and near-surface. Overall, the explosive hazard risk in the BZ – Game at the TOAR-FUDS is evaluated to be low-moderate, depending on proximity to IAs.

BZ – Park: A total of five UXO have been recovered during previous investigations in the BZ – Park portions of the TOAR-FUDS. No UXO was recovered during the RI. The Average UXO Density Expected, as calculated by UXO Estimator Module 2, based on the results of the RI using IAR and DGM data, are calculated to range from 0.018 to 0.11 UXO per acre for the BZ – Park areas of the TOAR-FUDS. Also, in general, UXO recovered previously in BZ – Park at the TOAR-FUDS have been recovered in the vicinity of IAs. This is indicative of the fact that UXO density in BZs is expected to vary based on proximity to IAs. These UXO could be lethal if detonated by an individual's activities. A number of visitors and hunters, estimated at 18 to 365 individuals per day, have the potential to come into contact with, and interact with, UXO located on the ground surface and near-surface. Overall, the explosive hazard risk in the BZ – Park at the TOAR-FUDS site is evaluated to be low-moderate, depending on proximity to IAs.

Lake Watawga Area: A total of four UXO have been recovered during all investigations, both on the surface and subsurface, in the Lake Watawga area. The Average UXO Density Expected at the Lake Watawga, as calculated by UXO Estimator Module 2, based on the results of the 2004 RI using IAR data, is 0.072 UXO per acre. It should be noted that although numerous DGM anomalies were detected and identified for intrusive sampling in the Lake Watawga UXO area, none of these DGM-selected anomalies were intrusively sampled due to explosive safety concerns with the nearby residential housing development adjacent to the northern boundary. As such, the calculated 0.072 UXO per acre density value in this area is based solely on the collected IAR data. The calculated UXO density also does not account for the two items recovered during the CENAB site visit. The Lake Watawga area is suspected to contain numerous UXO based on its location adjacent to and immediately downrange of the IAs – Park. These UXO could be lethal if detonated by an individual's activities. A number of visitors and hunters, estimated at 18 to 365 individuals per day in Park, have the potential to come into contact with, and interact with, UXO on the ground surface and near-surface. An additional human factors risk factor is the development of adjacent land for residential housing at Lake Watawga. The explosive safety risk in the Lake Watawga area portion of the TOAR-FUDS is evaluated to be high, based on the confirmed presence of UXO, the limited UXO data collected due to public safety concerns, its location immediately downrange of the IAs – Park, and the increasing populations associated with adjacent residential housing development.

Other Areas – Game and Other Areas – Park: No UXO have been recovered at the Other Areas – Game and Other Areas – Park portions of the TOAR-FUDS. The Average UXO Density Expected, as calculated by UXO Estimator Module 2, based on the results of the RI using IAR and DGM data, are calculated to range from 0.029 to 0.073 and 0.020 to 0.11 UXO per acre for Other Areas – Game and Other Areas – Park, respectively, at the TOAR-FUDS. The items recovered from the Other Areas included MD items and non-MEC-related items. The recovered items pose no explosive hazard risk. Although no UXO were recovered in Other Areas during the RI, since 37-mm, 75-mm, and 155-mm UXO items and MD were recovered in IAs and BZs adjacent to Other Areas at the TOAR-FUDS, their potential presence in Other

Areas, while low, cannot be ruled out. Therefore, although no UXO were recovered, their potential presence cannot be ruled out. These UXO, if present, could be lethal if detonated by an individual's activities. A number of visitors and hunters, estimated at 10 to 100 individuals per day in Game, and 18 to 365 individuals per day in Park, have the potential to come into contact with, and interact with, the land areas at the Other Areas. <u>Overall, the explosive hazard risk in the Other Areas – Game and Other Areas – Park portions of the TOAR-FUDS are evaluated to be low.</u>

Wet Areas: Approximately 25% of the TOAR-FUDS is covered by water features, including lakes, streams, ponds, and wetlands. Wet areas are present in each UXO source area at the TOAR-FUDS. No investigation was conducted for UXO in wet areas at the TOAR-FUDS due to high cost and safety hazards. <u>However, based on limited site accessibility, limited site activity, and low receptor population, the relative explosive hazard risk in wet areas at the TOAR-FUDS is evaluated to be low.</u>

7.1.4 Uncertainty Analysis

The risk evaluation for UXO at the TOAR-FUDS has identified the presence of explosive safety hazards, and has qualitatively evaluated these explosive safety hazards. This qualitative risk evaluation is based on the types and numbers of UXO items expected to remain at the TOAR-FUDS, the accessibility characteristics of the affected areas, along with the numbers and manner of human interactions with these residual UXO items.

A certain level of uncertainty is inherent in all human health risk assessments, and the UXO risk evaluation process for the TOAR-FUDS described herein is no different. The UXO risk evaluation is a qualitative, conditional estimate of the explosive safety hazards associated with potential interactions of human receptors to residual UXO items located on the TOAR-FUDS. This UXO risk evaluation is predicated on a number of assumptions and conditions, and is not intended to be a probabilistic estimate of risk.

The level of uncertainty associated with the conclusions of the UXO risk evaluation for the TOAR-FUDS are directly related to a number of factors, including:

- Qualitative nature of the risk evaluation.

- Preliminary remediation goal selection of 0.5 UXO/acre – Based on the general descriptions of land use for various target densities discussed in subsection 3.1.1.1.2, a target density of 0.5 UXO/acre across the entire site is conservative, particularly in Game. A target density of 1.0 UXO/acre in some areas may be appropriate.

- Estimates of UXO densities and receptor populations – UXO densities are based on various methods of investigation and approximate acreages. Receptor populations, particularly in Game, can only be estimated within a range of values.

- Confidence levels associated with UXO Estimator Module 2 – A 95% confidence level in UXO Estimator is conservative.

To address the uncertainty levels associated with this UXO risk evaluation, the UXO risk evaluation for the TOAR-FUDS has incorporated the following information:

- Average UXO Density Expected, as calculated by UXO Estimator Module 2, and generally confirmed by the results of the 2004 RI UXO site characterization results.

- Information from DCNR on the numbers of receptors who access the Tobyhanna State Park and their activities.

- Information from local sources on the estimated numbers of receptors who access the State Game Lands.

- Conservative estimates of the explosive safety hazards associated with the types of residual UXO and fuzing sensitivity.

In summary, the IAs on both the Park and Game portions of the TOAR-FUDS have "High" UXO explosive safety hazards as a result of the confirmed presence of UXO, UXO densities, site accessibility and receptor populations. The Lake Watawga portion of the TOAR-FUDS has a "High" explosive safety hazard based upon the confirmed presence of UXO, the UXO density, site accessibility, and associated receptor populations on residential property located adjacent to the northern FUDS property boundary. The BZ – Game and BZ – Park portions of the TOAR-FUDS have a "Low-Moderate" explosive safety hazard based on the confirmed presence of UXO, UXO density, site accessibility and receptor populations. The remaining portions of the TOAR-FUDS have "Low" explosive safety hazard rankings based on the UXO densities, site accessibility and receptor population characteristics.

7.2 SCREENING-LEVEL RISK ASSESSMENT FOR MUNITIONS CONSTITUENTS

This subsection provides an overview of the results of the screening-level risk assessment (SLRA) for MC (explosives and metals) for human health and the environment (i.e., ecological receptors). Due to the significant number of tables in this subsection, all referenced tables appear at the end of subsection 7.2.

The objective of both the human health and ecological screening-level risk assessments summarized in subsections 7.2.1 and 7.2.2 is to determine if concentrations of MC (explosives and metals) found at the site warrant further evaluation. As discussed in Subsection 3.2.1, MC sampling conducted at the TOAR-FUDS was conducted at biased high locations (IAs and FPs) to represent site conditions in areas with the highest potential for contamination based on historical use of the property as an artillery range. Because soil sampling for MC had not been conducted previously as part of a preliminary assessment (PA) or SI performed under CERCLA, SI-level sampling was conducted for MC as part of the RI to determine if additional MC sampling, analysis and/or evaluation was warranted.

7.2.1 Human Health Screening-Level Risk Assessment

The human health SLRA process used to evaluate MC sampling results is summarized as follows:

1. Develop a list of conservative risk-based human health benchmarks against which to compare soil sampling results. These human health criteria are provided in Table 7-8 and include: October 2004 EPA Region III RBCs (EPA, 2004), and the Pennsylvania Land Recycling Program Act 2 concentrations (as MSCs) for direct contact and soil to groundwater published in the 24 November 2001 edition of the *Pennsylvania Bulletin* (PADEP, 2001), and revised in December 2004.

2. Compare maximum soil concentrations against the lowest risk-based benchmarks for each chemical detected at the site to develop a list of contaminants of potential concern (COPCs). Chemical concentrations that exceed the lowest benchmark are selected as COPCs.

3. Calculate exposure point concentrations (EPCs) based on the 95% upper confidence limit of the arithmetic mean (95% UCL), using the EPA-approved ProUCL Version 3.0 software (EPA, 2004).

4. Conduct statistical comparison of site soil concentrations to background soil concentrations to determine if site soil concentrations are statistically similar to reference (i.e., background) values.

5. Evaluate uncertainties associated with the process.

6. Based on the results, determine if concentrations of MC in site soils warrants further consideration at an RI-level.

7.2.1.1 Land Use and Receptor Analysis

7.2.1.1.1 Current Use

The TOAR-FUDS consists of two adjacent land areas owned by the Commonwealth of Pennsylvania and divided by Interstate 380 (I-380). The northeastern portion is managed by the DCNR and is comprised of portions of Park. The southwestern portion is managed by the PGC and is comprised of portions of the Game (see Section 2). Both areas are currently used for outdoor recreation including hunting, hiking, camping and biking. It is the intent of the Commonwealth to maintain this land for continued recreational use.

7.2.1.1.2 Future Use

Although the Commonwealth has stated its intent to maintain the future use of Park and Game as recreational areas, the potential, though remote at this time, does exist for portions of these lands to be apportioned for other uses including commercial and possible residential use. As this assessment represents an SI-level screening assessment, a conservative bias was incorporated within. This assessment conservatively evaluated the potential risk to a residential receptor who may be exposed to COPCs detected in the soils on these lands. Should the results of this conservative screening indicate acceptable risk to the most highly exposed receptor population, then by corollary, there would be acceptable risk to less-exposed individuals (i.e. recreational users).

7.2.1.2 Sampling Data

The results of sampling were analyzed three ways in the SLRA: (1) results for Park and Game combined, (2) results for Park only, and (3) results for Game only. The results were analyzed multiple ways to ensure that elevated concentrations in either Park or Game would not be lost in a combined, site wide assessment. As part of the SLRA, sediment samples were grouped with soils for comparison against risk-based benchmarks. Comparisons with chemical-specific, risk-based concentrations that are protective of residential exposure to chemicals in soil are discussed in subsections 7.2.1.3 Data Evaluation and 7.2.1.4 Risk Characterization below. Note that this SI-level screening assessment was limited to an assessment of soils only. A detailed comparison of surface water results with federal and state ambient water quality criteria (AWQC) for the protection of human health was not performed since only lead and zinc were detected above reporting limits.

Human health-related AWQC criteria do not exist for lead and the AWQC criterion for zinc (federal criterion of 7,400 ug/l for water + organism consumption) is greater than 250 times the highest detected concentration of 27.7 ug/l. In addition, comparison of the surface water samples collected at TOAR (i.e., biased high locations from wetlands) to human health-related AWQC is unrealistic due to the limited exposure potential to surface water (from intermittent hiking, hunting, camping, etc.) in both Park and Game. As described in EPA-822-B-00-004, *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000)*, "AWQC for the protection of human health are designed to minimize the risk of adverse effects occurring to humans from chronic (lifetime) exposure…" (EPA, 2000) and are based on a drinking water intake (from surface waters) of 2 liters per day plus a fish consumption rate of 17.5 gram per day. Therefore, a detailed evaluation of surface water results was only conducted relative to ecological criteria as summarized in subsections 7.2.2.4.1.6 and 7.2.2.4.2.7 for Game and Park, respectively.

7.2.1.3 Data Evaluation and Selection of COPCs

Tables 7-9 through 7-11 are the "Occurrence, Distribution, and Selection of COPC" tables (RAGS Part D, Tables 2.1 through 2.3) for the surface soils combined with sediments for the combined Park and Game Site, the Park, and the Game areas, respectively, and represent the COPC screening results based on the minimum of PADEP and EPA Region III soil screening criteria (Table 7-8). Additionally, Table 7-12 is included to show the two test pit samples. The minimum and maximum concentrations, maximum concentration locations, the frequencies of detection, and the lowest human health benchmarks (i.e., risk-based screening concentrations [RBSCs], MSCs) are presented. The COPC flags indicate those chemicals that exceeded their benchmarks (i.e., "Yes" or "No"). The site maximum of each detected soil chemical was compared with the appropriate chemical-specific, human health benchmark value developed for residential use. The maximum soil concentration for each detected chemical was selected from the pool of site data.

Tables 7-13 through 7-15 (RAGS Part D, Tables 3.1 through 3.3) present the medium-specific EPC summaries for the COPCs in the combined Park and Game samples, the Park only samples, and the Game only samples, respectively. Table 7-16 presents the EPC summary for arsenic in the two test pit samples. Because a UCL could not be calculated for the test pit samples due to insufficient sample size, the EPC defaulted to the maximum detected concentration. EPCs are defined as the lower of the maximum reported concentration or its 95% UCL.

In addition, the ProUCL distribution results are shown in the tables. Appendix O provides documentation of the statistical tests that were performed.

7.2.1.4 Risk Characterization

The following narrative discusses the results of the screening analysis conducted herein and as such presents a preliminary characterization of the potential risk to future residents who may be exposed to chemicals in soil.

7.2.1.4.1 Residential Screening Results

Maximum concentrations of 4 of the 14 detected chemicals exceeded the chemical-specific screening criteria for residential exposure (Tables 7-9 and 7-10) for the combined Park and Game samples and the Park samples. Based on these results, the following chemicals were selected as COPCs:

- Antimony
- Arsenic
- Lead

- Thallium

Maximum concentrations of 3 of the 13 detected chemicals exceeded the lowest chemical-specific screening criteria (Table 7-11) for the Game samples. Based on these results, the following chemicals were selected as COPCs:

- Antimony
- Arsenic
- Thallium

Of the 14 detected chemicals only arsenic exceeded the lowest chemical-specific screening criteria (Table 7-12) for the test pit samples.

7.2.1.4.2 Potential Risk Associated with Exposure to Lead in Soil

EPA has developed the Adult Lead Model (ALM) (EPA, 1996) to estimate the impact of environmental lead at hazardous waste sites. The ALM predicts a preliminary remediation goal (PRG) for lead in soils based on incidental soil ingestion by a woman of childbearing age such that the fetal blood level will not exceed 10 micrograms per deciliter (µg/dL). The model requires default and/or site-specific inputs by the user and have been developed based on empirical scientific human data on lead exposure, behavioral variables, and blood levels, and on the pharmacokinetics of lead in the tissues of animals and humans. The default lead concentrations and exposure input values recommended for the ALM are based on experimental data (EPA, 1996). Site-specific exposure assumptions were used for inputs when appropriate data were available.

The ALM has default input assumptions that can be modified if site-specific data are available. The defaults are based on averages or ranges of empirical data from peer-reviewed studies of the human population (EPA, 1996). The model user has the option of choosing values within the default ranges based on site-specific information concerning the nature of the population that may be exposed at the site. For those exposure inputs and assumptions having a range of possible values, a single input was selected for this evaluation as shown in the following bullets:

- The older child recreational user was assumed to ingest 100 mg/day of soil, as recommended for children by the *Exposures Factors Handbook* (EFH) (Table 4-23; EPA, 1997). The EHF (EPA, 1997) recommends 50 mg/day as a reasonable central estimate of adult soil ingestion for industrial settings and 100 mg/day for residential and agricultural settings. The soil ingestion rate for the Park Ranger was assumed to be 100 mg/day as a conservative assumption based on EFH recommendations and professional judgment.

- The old child recreational user was assumed to visit the site 90 days per year, the minimum exposure frequency default. The Park Ranger was assumed to work 250 days per year. Both assumptions are conservative.

- EPA estimates that 1.8 to 2.1 is a plausible range for the geometric standard deviation (GSD), based on an evaluation of available blood lead concentration data for different types of populations nationwide. Higher values in the range would be more reflective of a heterogeneous population. Lower GSD values in the range would reflect less inter-individual variability such as seen in populations within a localized area and who share the same ethnic, cultural, or socioeconomic factors. In cases where site-specific data are not available, a value within this range will be selected based on an assessment as to whether the population at the site would be expected to be more or less heterogeneous. It was assumed that 96.7% of the local area population is white (non-Hispanic). Based on Table A-1 of the ALM (NHANES III Phase I Summary Statistics) (EPA, 1996), it was determined that the average GSD of non-Hispanic whites of the 17- to 45-year old group was 1.89. This value will be used as an input to the model.

- The baseline blood lead concentration used in the ALM is intended to represent the best estimate of a reasonable central background blood lead value (geometric mean; GM) in women of childbearing age. This background level reflects exposure to lead sources other than the site, such as diet, drinking water, and soils/dust contaminated by background sources. In the absence of high quality data for the site, baseline blood lead concentrations may be extrapolated from estimates for other surrogate populations that would be expected to have a similar blood lead distribution as that of the population of concern. The plausible blood level range proposed by EPA is 1.7 to 2.2 μg/dl (EPA, 1996). As stated previously, it is assumed that 96.7% of the local area is white (non-Hispanic). Based on Table A-1 of the ALM (NHANES III Phase I Summary Statistics) (EPA, 1996), it was determined that the GM of non-Hispanic whites of the 17- to 45-year old group was 1.70 μg/dl. This value will be used as an input to the model.

Lead was selected as a COPC because its maximum detected level (Tables 7-9 and 7-10) was 611 mg/kg, which exceeded the 500 mg/kg PADEP Act 2 soil to groundwater MSC. Lead was evaluated using the ALM.

The ALM was run for the older child recreational user and the adult Park Ranger. The soil lead PRGs predicted by the model for the older child recreational user and Park Ranger scenarios were 1,858 and 669 mg/kg, respectively. Tables 7-17 and 7-18 show these results. The site-wide, average lead level for the combined Park and Game soils at the TOAR-FUDS was calculated as 101 mg/kg. The mean was based on a total of 45 samples with a 100% detection frequency. The average soil lead concentration was well below the model PRGs for the older child recreational user and Park Ranger. Lead is not considered to be at levels of concern.

7.2.1.5 Comparison of Site Data with Background (Reference) Data

The objective of this comparison was to determine if the concentrations of COPCs in site soils were from the same population as COPC levels observed in the reference data. Table 7-19 summarizes the reference data for the Park and Game soils. The table presents the detection frequency, range of detected concentrations, range of sample quantitation limits (SQLs), arithmetic mean concentration, standard deviation, data distribution, and the 95% UCL of the mean for each chemical detected. Eight reference soil samples were collected (Park $n = 4$; Game $n = 4$). Although beryllium and thallium were not detected in any of the reference samples, they were presented for a statistic ready comparison with the site data.

The ProUCL distribution results were calculated for all reference soils and are shown in Table 7-19. According to EPA's ProUCL program, all the reference data had a normal distribution (Student's t-UCL). The nonparametric Mann-Whitney test (Gilbert, 1987) was used to perform a statistical comparison of the site data to the background data. Appendix O provides documentation of the statistical tests that were performed.

7.2.1.5.1 Combined Park and Game Soils

Table 7-20 summarizes the results of the statistical comparison of the combined Park and Game data and the background data. Combined Park and Game soil levels of antimony, arsenic, lead, and thallium were statistically compared with background data (Table 7-20). The statistical evaluation showed that the distribution of arsenic, lead, and thallium soil levels were not statistically different from background soil distribution. However, antimony levels at the site were found to be significantly different from the background data.

7.2.1.5.2 Park Soils

Table 7-21 summarizes the results of the statistical comparison of the Park data and the background data. Park soil levels of antimony, arsenic, lead, and thallium were statistically compared with background data (Table 7-21). The statistical evaluation showed that the distribution of arsenic and thallium soil levels were not statistically different from background soil distribution. However, antimony and lead levels at the site were found to be significantly different from the background data.

7.2.1.5.3 Game Soils

Table 7-22 summarizes the results of the statistical comparison of the Game data and the background data. Game soil levels of antimony, arsenic, and thallium were statistically compared with background data (Table 7-22). The statistical evaluation showed that the distribution of arsenic and thallium soil levels were not statistically different from background soil distribution. However, antimony levels at the site were found to be significantly different from the background data.

Antimony and lead are further discussed in Subsection 7.2.1.4, Discussion and Uncertainty Analysis.

7.2.1.6 Discussion and Uncertainty Analysis

An SI level screening of the human health risk associated with potential exposure to soil was performed. Although the sites are currently used for hunting, hiking, camping and other forms of recreation and this is also the projected long-term use, a conservative screening level assumption was made that evaluated the remote possibility of a future residential use of portions of the property. Comparisons of soil concentrations with chemical-specific, risk-based concentrations protective of residential exposure to soil were made and have been discussed in the Risk Characterization. In addition, the chemical concentrations were compared statistically with reference soil levels to determine the extent to which the concentrations in site soils reflected ambient conditions. Of the chemicals detected in soils, only antimony and lead exceeded both the risk based concentrations (at a few sampling locations) and reference soil levels. The potential risk associated with each of thee metals is discussed below.

7.2.1.6.1 Antimony

Although antimony was found to be significantly different from background soil levels (combined Park and Game samples, and Park only samples), it exceeded the lowest screening benchmark in only 6 of the 45 analyzed samples. The lowest screening benchmark was the residential soil RBC (3.13 mg/kg) which was adjusted for preliminary screening purposes to a target hazard quotient (THQ) of 0.1. Furthermore, the maximum concentration of antimony detected at the site (10 mg/kg) does not exceed the residential RBC at a THQ of 1.0 (31.3 mg/kg), the industrial RBC (40.9 mg/kg), PADEP MSCs for direct contact (1,100 mg/kg), or soil to groundwater protection (600 mg/kg). It is reasonable to conclude that site antimony levels are not likely to pose a human health threat at the TOAR-FUDS.

7.2.1.6.2 Lead

Although lead was found to be statistically significant different from background soil levels (Park only samples), it exceeded the lowest screening benchmark in only 1 of the 45 analyzed samples with a concentration of 611 mg/kg. The lowest screening benchmark was the PADEP Act 2 soil to groundwater MSC (500 mg/kg). The arithmetic mean for lead for the Park data (with the highest mean of all three areas) was 136 mg/kg, which is well below the soil to groundwater MSC. It is reasonable to conclude that site lead levels are not likely to pose a human health threat at the TOAR-FUDS.

7.2.2 Ecological Screening-Level Risk Assessment

7.2.2.1 Introduction

This screening level ecological risk assessment (SLERA) was performed to provide an initial characterization of the potential risks to ecological receptors at the TOAR-FUDS and to determine if additional ecological evaluation is needed. Further, this evaluation provides information to establish the extent to which the site poses an ecological risk and whether some form of remediation for protection of ecological receptors is necessary. This multi-pathway analysis was based on reasonable, protective assumptions about the potential for ecological receptors to be exposed to, and to be adversely affected by, exposure to chemicals of potential ecological concern (COPECs).

The process used to conduct the SLERA is based generally on the initial two steps of an eight-step iterative process for an ERA described in the *Ecological Risk Assessment Guidance for Superfund* (EPA, 1997e). This methodology incorporates the basic and fundamental approach to performing ERAs outlined by EPA's Risk Assessment Forum in its *Framework for Ecological Risk Assessment* (Framework) (EPA, 1992c) and *Guidelines for Ecological Risk Assessment* (Guidelines) (EPA, 1998e). The eight-step approach outlined in the *Ecological Risk Assessment Guidance for Superfund* consists of the following steps:

1. Screening-level problem formulation and ecological effects evaluation.
2. Screening-level preliminary exposure estimates and risk calculation.
3. Baseline risk assessment problem formulation.
4. Study design and DQOs.
5. Field verification of sampling design.
6. SI and analysis of exposure and effects.
7. Risk characterization.
8. Risk management.

As stated here, the SLERA process used for this evaluation is based generally on the first two steps of this process; it is not intended to meet the requirements of a quantitative-level risk assessment.

Also note that as an SI-level ecological screening assessment, this document is not intended to strictly follow the format of the SLERA process outlined by EPA for a BERA. For example, although headings of Problem Formulation, Analysis Phase and Rick Characterization are not presented, the technical elements of each are largely incorporated in this screening. It should also be noted that to avoid redundancy, some of the information expected within the body of the assessment is presented in other sections of the report. For example the information that would be presented in the Problem Formulation, i.e., discussion of potentially affected habitats and floral and faunal receptor populations within those habitats, identification of threatened and endangered species occurring or expected to occur on the sites, etc, have been presented previously in Section 2 of this report.

7.2.2.2 Environmental Setting

As noted above, a detailed description of the environmental setting at the TOAR-FUDS, including ecosystems, wildlife, and species of special concern, is provided in Subsection 2.3.

7.2.2.2.1 Game and Park Pathways Analysis

Based on the current understanding of the ecology of Game and Park, and the potential distribution of munitions constituents in the surface waters and soils in these areas, a pathways analysis has been developed. The pathways analysis is presented as a flow diagram that provides a working, dynamic representation of the relationships that exist between the chemical stressors and the key ecological receptors. Figure 7-4 provides a graphical presentation of the potential movement of munitions constituents through the aquatic habitats in Game and Park, key floral and faunal receptors inhabiting or foraging these surface waters, and the mechanism(s) of exposure, and the potential exposure of terrestrial receptors inhabiting Game and Park to munitions constituents.

7.2.2.2.2 Assessment and Measurement Endpoints

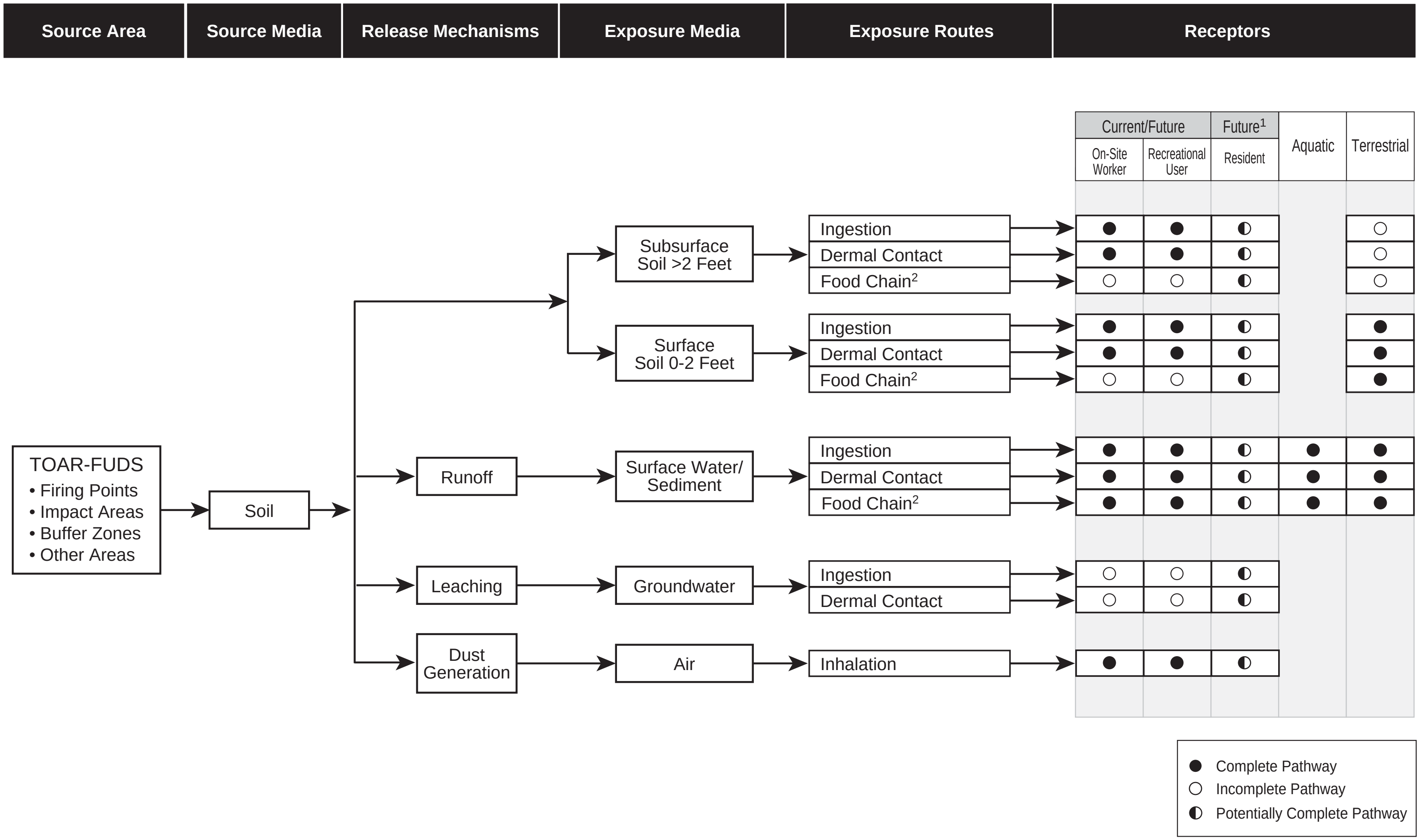
Knowledge of the relationship of site-related contamination to ecological endpoints contributes significantly to the SLERA decision-making process (Suter, 1989). In this assessment, an endpoint is defined as an ecological characteristic (e.g., avian reproduction) that may be adversely affected by exposure to munitions constituents. Assessment endpoints describe the ecological characteristics that are to be evaluated and protected. Measurement endpoints, now referred to as "measures of effect", link or evaluate the site-specific conditions of exposure and toxicity with the assessment endpoints to be protected.

Table 7-23 presents the assessment and measurement endpoints for aquatic and terrestrial habitats of Game and Park that are addressed in this assessment.

7.2.2.3 Data Evaluation and Screening Level Benchmark Selection

The results of environmental sampling were analyzed three ways in the SLERA: (1) results for Park and Game combined, (2) results for Park only, and (3) results for Game only. The results

Figure 7-4 Munitions Constituents Exposure Pathways Analysis for the TOAR-FUDS



[1]The future anticipated land use for the TOAR-FUDS is recreational. Future residents are not anticipated.

[2]Food chain refers to direct foraging and food chain dynamics.

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were analyzed three ways to ensure that elevated concentrations in either Park or Game would not be lost in a combined site wide assessment.

The following samples were collected from within ordnance features to screen for MC at the TOAR-FUDS site:

- Game:
  - 22 surface soil (evaluated with surface soil and sediment combined)
  - 3 sediment (evaluated with surface soil and sediment combined)
  - 3 surface water
- Park:
  - 18 surface soil (evaluated with surface soil and sediment combined)
  - 2 sediment (evaluated with surface soil and sediment combined)
  - 2 surface water

Separate data summary tables are presented for Game and Park for those chemicals that were detected at least once within a medium (see Tables 7-24 through 7-29). If the chemical was not detected in any medium at any location, that chemical was omitted from further evaluation. To evaluate the sensitivity of the analytical methods used in this assessment, SQLs were compared with screening benchmarks for those chemicals that were never detected (see Table 7-47) and are discussed in the uncertainty section in Subsection 7.2.2.5.

7.2.2.3.1 Screening Level Benchmarks

Numerous types of screening level ecological toxicity benchmarks have been developed to be protective of organisms using a variety of habitats. As a consequence, the ecological benchmarks represent medium-specific contaminant concentrations considered protective of biota inhabiting that medium. Ecological benchmarks were obtained from a variety of sources including Federal and state regulatory values, EPA, and other agency reports, and scientific literature.

Within the TOAR-FUDS, the potential direct exposure media include soil, sediment, and surface water. As such, the ecological benchmarks presented in the following subsections were compiled:

7.2.2.3.1.1 Soil Benchmarks

The following sources were used to obtain soil benchmarks:

- **EPA (2005)—***Interim Ecological Soil Screening Levels (Eco-SSLs)*. These soil screening levels are recently published benchmark values for the evaluation of soil data. To the extent data are available, Eco-SSLs are derived for the evaluation of toxicity to plants, soil invertebrates and avain and mammalian species that forage on plants and soil invertebrates. The 2005 list provided screening levels of 11 metals and 2 organics although values for other chemicals are pending final review.

- **Oak Ridge National Laboratory (ORNL) (1997a)—*Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants.*** Phytotoxicological benchmarks were derived using the same methodology used to generate the earthworm benchmarks. Phytotoxicological benchmarks were derived by rank-ordering the lowest-observed-effect-concentration (LOEC) values drawn from the literature.

- **ORNL (1997b)—*Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Processes.*** Earthworm and microbial benchmarks were derived by rank-ordering LOEC values gathered from an extensive literature search, then selecting the 10th percentile LOEC value as the benchmark. The 10th percentile LOEC value was selected as the benchmark, so the "assessor should be 90% certain of protecting plants growing in the site soil."

- **ORNL (1997c)—*Preliminary Remediation Goals for Ecological Endpoints.*** Wildlife PRGs for soil were derived by iteratively calculating exposure estimates using different soil concentrations and soil-to-biota contaminant uptake models. Uptake models for plants, earthworms, and small mammals were derived from various sources. Because diets dramatically influence exposures and sensitivity to contaminants varies among species, PRGs were developed for six species: short-tail shrew, white-footed mouse, red fox, white-tailed deer, American woodcock, and red-tailed hawk. The wildlife screening values (i.e., PRGs) were based on the lowest-observed-adverse-effect levels (LOAELs) of the selected toxicity studies. By definition, a LOAEL is the lowest dose of a chemical that produces statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and its appropriate control (Dourson and Stara, 1983). The LOAEL values were converted to no-observed-adverse-effect level (NOAEL) values by dividing by a factor of 10. Note that although the factor of 10 is a commonly applied conversion between LOAELs and NOAELs, it is felt to be an upper-bound estimate of the potential extrapolation. Comparisons of studies (McNamara, 1976; Weil and McCollister, 1963) for which NOAELs and LOAELs were provided, indicate that 96% of the chemicals evaluated for both rodent and non-rodent receptors had LOAEL/NOAEL ratios of five or less (Dourson and Stara, 1983). It is expected that a 10-fold extrapolation factor may over-estimate the potential ecological risk.

- **EPA (1995c)—*Region III Biological Technical Assistance Group (BTAG) Screening Levels.*** BTAG screening levels are conservative guidelines for the evaluation of soil data at Superfund sites. BTAG screening levels are based on the lowest value from a combination of sources considered to be protective of the most sensitive organisms in soil. Sources for the development of these screening values included peer-reviewed literature, regulatory agency criteria, and technical expertise from various agencies.

7.2.2.3.1.2 Sediment Benchmarks

The following sources, in order of preference, were used to obtain sediment benchmarks:

- **Canadian Council of Ministers of the Environment (CCME) (2001)—*Canadian Sediment Quality Guidelines***. The Water Quality Guidelines Task Group of CCME developed probable effect levels (PELs) for the protection of aquatic life for freshwater sediments using a combination of the National Status and Trends Program (NSTP) approach and the Spiked-Sediment Toxicity Test (SSTT) approach (CCME, 1995). PELs are numerical limits recommended to support and maintain aquatic life associated with bed sediments. Concentrations of a specific chemical greater than its PEL have been determined to cause an adverse effect on aquatic life.

- ***Ontario Ministry of the Environment and Energy (OMEE) Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* (Persaud et al., 1996).** OMEE provides lowest effect levels (LELs) for various metals, pesticides, polycyclic aromatic hydrocarbons (PAHs), and PCBs in freshwater sediments. LELs represent the level of contamination that is not expected to have an effect on the majority of sediment-dwelling organisms. LELs are based on the 5th percentile of the screening level concentration (SLC). The SLC is based on the occurrence of benthic infaunal species and concentrations of contaminants, and is an estimate of the highest concentration of a contaminant that can be tolerated by a specific proportion of benthic species (Neff et al., 1986).

- **EPA Region III BTAG Screening Values (1995c)**—These benchmarks represent screening values for flora and fauna that inhabit sediments. These benchmarks make no distinction between freshwater and marine sediments. The values provided herein represent a combination of low-level effects range-low (ER-L) values and other endpoints, such as apparent effects thresholds (AET).

- **National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Tables (1999)**—NOAA provides screening concentrations for inorganic and organic contaminants in various environmental media, as well as guidelines for preserving samples and analytical technique options. These benchmarks were developed to identify potential impacts to coastal resources and habitats likely to be affected by hazardous waste sites and are also helpful to anyone who is evaluating the potential risk from contaminated water, sediment, or soil. These freshwater PELs are based on benthic community metrics and toxicity tests results.

7.2.2.3.1.3 Surface Water Benchmarks

The following sources were used to obtain surface water benchmarks:

- ***Federal Ambient Water Quality Criteria (AWQC) for the Protection of Aquatic Life* (EPA, 2002b)**—This document provides a compilation of the national recommended water quality criteria (WQC) for a wide variety of pollutants, predominantly metals and pesticides. Two sets of criteria are provided in this guidance, i.e., criteria maximum concentrations (CMCs), and criteria continuous concentrations (CCCs). CMCs represent acute criteria applied as 1-hour average concentrations not to be exceeded more than once in any 3-year period. CCCs represent chronic criteria applied as 4-day average concentrations not to be exceeded more than once in any 3-year period. CCCs will be used to determine COPECs for this Tier I ERA. As with the VA criteria, several of the metals criteria are hardness-dependent. The same approach to calculating hardness-dependent criteria will apply.

- **Pennsylvania Water Quality Criteria (PA Code, Title 25, Chapter 16)**—The Commonwealth of Pennsylvania has derived water quality criteria for the protection of fish and other aquatic life. As in the Federal AWQC (EPA, 1999), two sets of criteria are provided: an acute criterion, CMCs are surface water criteria applied as 1-hour average concentrations not to be exceeded more than once any 3-year period. CCCs represent surface water values applied as four-day average concentrations not to be exceeded more than once in any 3-year period.

7.2.2.4 Screening Analysis

7.2.2.4.1 Screening Comparison with Ecological Benchmarks

For this assessment and specifically to assess exposure to chemicals in soils, a two-tiered or two-level screening comparison was performed. In the Level 1 screen, the maximum detected surface soil concentrations were compared with the appropriate screening benchmarks. Note that because aquatic organisms (e.g., invertebrates) demonstrate minimal migratory behavior, sample-by-sample comparisons were conducted for the sediment and surface water pathways. If the maximum detected concentration of a chemical exceeded any of its respective medium-specific benchmarks, it was retained as a COPEC. In addition, if a benchmark was not available for a chemical, it was also retained as a COPEC.

For those COPECs retained for further analysis, a Level 2 screen was performed. In the Level 2 screen, EPCs were derived from the 95% UCLs of the mean of the appropriate data distributions based on the use of the EPA's Pro-UCL program. Wildlife exposure to chemicals in soil was evaluated as an aggregate of the soil data collected in Game and in Park. As with the Level 1 screening comparison, the EPCs were also compared with each of the soil-specific screening level benchmarks. It should be noted that this approach introduces some uncertainty into the assessment of exposure and consequent risk. The aggregation of data while appropriate for some wide-ranging terrestrial species, e.g., white-tailed deer, may not be appropriate for those species whose home ranges are quite small, e.g., deer mouse. For these species, it may be more appropriate to combine and evaluate samples at a much smaller spatial scale.

Comparisons of the Game and the Park soil (Tables 7-30 and 7-31 and Tables 7-39 and 7-40, respectively), sediment (Tables 7-33 through 7-35 and Table 7-42, respectively), and surface water (Tables 7-37 and 7-44) data with the appropriate benchmarks are discussed below.

7.2.2.4.2 Site Soil Comparison with Background Soils

Certain chemicals, primarily inorganics, occur naturally in the environment and may not be present at a site due to site-related activities. To ensure that the evaluation focuses on site-related chemicals, a background screen was conducted. The reference surface soil screening levels for inorganic chemicals are presented in Table 7-46. The reference screening methodology used for this assessment is that previously developed by the Army and USEPA Region 3 BTAG for SLERAs performed at Letterkenny Army Depot, Chambersburg, PA. This methodology states that any sample or sample location for which the ratio of the metal concentration and the maximum reference concentration for that metal is below 3 (i.e., site concentration/maximum background concentration) is considered to be within the natural variability of background level of the metal in soil. Background sediment and surface water concentrations were obtained from the TYAD ERA, 1997. Comparisons of the Game and the Park soil (Tables 7-32 and 7-41, respectively), sediment (Tables 7-36 and 7-43, respectively), and surface water (Tables 7-38 and 7-45, respectively) data with the appropriate reference levels are discussed below.

In addition to the use of the background screening approach described above, a statistical evaluation of the concentrations of the inorganic munitions constituents in Game and Park soils and the concentrations observed in the reference soils was performed. The ProUCL distribution results were calculated for the inorganic chemicals detected in all reference soils and are shown in Table 7-46. The nonparametric Mann-Whitney test (Gilbert, 1987) was used to perform a statistical comparison of Game soil data and the background data. A similar analysis was performed for Park soils. Appendix O provides documentation of the statistical tests that were performed. Note that due to sample size limitations, statistical tests were not performed for surface water and sediment.

7.2.2.5 Ecological Effects Characterization

7.2.2.5.1 Results of Screening Analysis

7.2.2.5.1.1 Game

The evaluation of the combined soils and sediments, sediments, and surface water in Game is presented in this subsection. Soils, sediments, and surface water were analyzed for explosives and metals. As summarized in Table 7-24, 25 soil and sediment samples and 4 duplicate samples were analyzed to evaluate ecological risk in Game. Tables 7-25 and 7-26 each contain three samples and one duplicate sample for sediments and surface water in the Game, respectively. Each summary table contains the frequency of detection, range of detected concentrations, SQLs, arithmetic mean, standard deviation, and 95% UCL.

7.2.2.5.1.1.1 Soils at Game - Level 1 Screen

A total of 13 inorganic analytes were detected in the soils and sediments of Game. The inclusion of the sediment data with the surface soils is based on the likelihood that the sediments are seasonally dry for a portion of the year. Additionally, sediments are evaluated separately and compared with sediment benchmarks to account for exposure of sediment-dwelling organisms during wet periods. All detected chemicals were evaluated using the Level 1 SLERA process.

Table 7-30 presents the Level 1 comparison of the maximum detected surface soil (and sediment) concentrations with the ecological screening values for soil for each chemical. This table also presents the ratio of the maximum concentration for each of the analytes detected in surface soils (for which ecological screening levels exist) with the lowest ecological screening benchmark evaluated. Shaded values indicate those screening levels that were exceeded.

The results of this comparison indicate that the maximum concentration of the 13 inorganic chemicals detected exceed their lowest ecological screening benchmarks. These metals are as follows (ratio of maximum detected concentration to benchmark in parentheses):

- Antimony (28)
- Arsenic (22)
- Beryllium (50)
- Cadmium (2.8)
- Chromium (1,567)
- Copper (2.2)
- Lead (37,500)
- Mercury (5,098)
- Nickel (5.75)
- Selenium (110)
- Silver (122,449)
- Thallium (1,400)
- Zinc (136)

The 13 metals for which the maximum soil concentrations exceeded the screening values were carried forward to Level 2 of the screening analysis.

7.2.2.5.1.1.2 Soils at Game - Level 2 Screen

Table 7-31 presents the Level 2 comparison of the EPCs with the ecological soil screening values. The EPC represents the lower of either the 95% UCL of the mean soil concentration or the maximum detected soil concentration in the surface soils (i.e., 0 to 0.5 ft bgs). Although the EPC to benchmark ratios are less than the maximum concentration to benchmark ratios, soil concentrations of all metals with the exception of copper, still exceeded their lowest ecological benchmark. Soil concentrations of the 13 metals that exceeded ecological benchmarks are evaluated further in the following subsections.

7.2.2.5.1.1.3 Reference Soils Comparison

A qualitative comparison between site soils and reference soils was performed for each of the 13 metals identified in the Level 1 analysis that had maximum detected concentrations greater than their respective benchmarks.

The results of the qualitative comparisons are presented in Table 7-32. The table prepared for Game presents the concentration of each of the 13 metals detected at each sample location and the maximum detected concentration in reference soils (see Table 7-46). The table also shows the ratio of the detected concentrations at Game to the maximum detected reference surface soil concentration for each sample. A ratio of 3.0 is the maximum threshold for which site concentrations are considered to be within the range of natural variability of the metal in soil. Note that qualitative comparisons for beryllium and thallium were conducted using the maximum quantitation limit rather than the maximum detected concentration because beryllium and thallium were not detected in the surface soils at the reference site.

The results of this qualitative comparison indicate that 11 of the 13 metals were present in concentrations that were less than the 3x reference background maximum concentrations (i.e., within the natural range of those metals in soil). The potential ecological risk associated with these 11 metals (arsenic, beryllium, cadmium, chromium, copper, mercury, nickel, selenium, silver, thallium, and zinc) may not be attributable to previous site activities, but rather may be due to naturally occurring concentrations of these metals in the soil. Note that antimony and lead were present in concentrations that exceeded background levels in only one sample location.

The results of the statistical comparison of the concentrations of inorganic constituents in Game soils with those observed in reference soils are presented in Table 7-48. Based on this analysis, only the soil concentrations of antimony were found to be significantly higher than the levels of those same constituents in reference area soils. As previously noted, antimony was present at a level that exceeded background levels of that metal at only one sample location.

7.2.2.5.1.1.4 Sediments at Game - Level 1

Tables 7-33 through 7-35 present a comparison of the detected sediment concentration and the ecological screening values for sediments for each compound detected at each sediment sample location. These tables also present the ratio of the detected concentration for each of the analytes detected in Game sediments (for which ecological screening levels exist) with the lowest ecological screening benchmark evaluated. Shaded values indicate those screening levels that were exceeded.

A total of 12 metals were detected in some or all of the sediment samples collected to characterize aquatic habitat. Of these detected chemicals, seven metals were detected in sediment samples in concentrations that exceeded sediment screening values: arsenic, cadmium, chromium, copper, lead, mercury, and selenium.

Beryllium was present in sediment samples but did not have a sediment screening criterion available for comparison.

7.2.2.5.1.1.5 Sediments at Game - Level 2

The Level 2 analysis (i.e., a comparison of EPCs with ecological benchmarks for sediments) was not performed because sediment samples were evaluated independently.

7.2.2.5.1.1.6 Qualitative Reference Sediments Comparison

A qualitative comparison between Game sediments and reference sediment concentrations is provided herein for the metals that exceeded ecological screening values at the site and the one additional metal for which screening criteria have not been developed. This reference comparison is presented in tabular format in Table 7-36. As in the quantitative reference comparison presented for soils, ratios of the sample concentration to the reference sediment maximum concentration were calculated. Ratios greater than 3 are considered to exceed the natural variability of the metal concentration in soils.

Of the eight metals evaluated, all were present in concentrations in Game sediments that are within the background threshold. The potential ecological risk associated with these five metals in sediment (arsenic, cadmium, copper, lead, and selenium) may not be attributable to previous site activities. Because these concentrations fall within naturally occurring levels of these metals in the reference sediment, ecological risk associated with exposure to these metals is not expected to be different from that of background levels. Because beryllium, chromium, and mercury were not detected in reference sediments, site concentrations could not be compared to background threshold levels.

7.2.2.5.1.1.7 Surface Water at Game - Level 1

Table 7-37 presents a comparison of the detected surface water concentration and the ecological screening values for surface water for each compound for each sampled location for metals. These tables also present the ratio of the detected concentration for each of the analytes detected in Game surface water (for which ecological screening levels exist) with the lowest ecological screening benchmark evaluated. Shaded values indicate those screening levels that were exceeded.

A total of 10 metals were detected in some or all of the surface water samples collected to characterize aquatic habitat. Of these detected chemicals, three metals were detected in surface water samples in concentrations that exceeded surface water screening values: cadmium, copper, and lead. Beryllium was present in surface water samples and did not have surface water screening criterion available for comparison.

7.2.2.5.1.1.8 Surface Water at Game - Level 2

The Level 2 analysis was not performed because surface water samples were evaluated independently.

7.2.2.5.1.1.9 Qualitative Reference Surface Water Comparison

A qualitative comparison between Game surface water and reference surface water concentrations is provided here for the metals that exceeded ecological screening values at the site and the one additional metal for which screening criteria has not been developed. This reference comparison is presented in tabular format in Table 7-38. As in the quantitative reference comparison presented for soils, ratios of the sample concentration to the reference surface water maximum concentration were calculated. Ratios greater than 3 are considered to exceed the natural variability of metals in surface water.

Of the four metals evaluated, only copper concentrations were present in Game surface water that were within the background threshold. The potential ecological risk associated with these copper concentrations may not be attributable to previous site activities. Because these concentrations fall within naturally occurring levels of these metals in the reference surface water, ecological risk associated with exposure is not expected to be different from that of background levels. Because beryllium and cadmium were not detected in reference sediments, site concentrations could not be compared to background threshold levels. Note that lead had only one ratio that was higher than 3.0 (ratio of 7.65).

7.2.2.5.1.2 Park

The evaluation of Park combined soils and sediments, sediments, and surface water is presented this subsection. Soils, sediments, and surface water were analyzed for explosives and metals. As summarized in Table 7-27, 20 soil and sediment samples and 1 duplicate sample were analyzed to evaluate ecological risk at Park. Tables 7-28 and 7-29 each contain two samples for sediments and surface water in the Park, respectively. Additionally, each summary table contains the frequency of detection, range of detected concentrations, SQLs, arithmetic mean, standard deviation, and 95% UCL.

7.2.2.5.1.2.1 Soils at Park - Level 1

A total of 13 inorganic analytes and 1 explosive (HMX) were detected in the soils and sediments of Park. The inclusion of the sediment data with the surface soils is based on the likelihood that the sediments are seasonally dry for a portion of the year. Additionally, sediments are evaluated separately and compared to sediment benchmarks to account for exposure of sediment-dwelling organisms during wet periods. All detected chemicals were evaluated using the Level 1 SLERA process.

Table 7-39 presents the Level 1 comparison of the maximum detected surface soil (and sediment) concentrations with the ecological screening values for soil for each chemical. This table also presents the ratio of the maximum concentration for each of the analytes detected in surface soils (for which ecological screening levels exist) with the lowest ecological screening benchmark evaluated. Shaded values indicate those screening levels that were exceeded.

The results of this comparison indicate that the maximum concentration of the 13 inorganic chemicals detected exceed their lowest ecological screening benchmarks. These metals are as follows (ratio of maximum detected concentration to benchmark in parentheses):

- Antimony (37)
- Arsenic (23)
- Beryllium (85)
- Cadmium (4.7)
- Chromium (1,547)
- Copper (11)
- Lead (61,100)
- Mercury (9,216)
- Nickel (6.8)
- Selenium (224)
- Silver (86,735)
- Thallium (880)
- Zinc (181)

The 13 metals for which the maximum soil concentrations exceeded the screening values were carried forward to Level 2 of the screening analysis.

7.2.2.5.1.2.2 Soils at Park - Level 2

Table 7-40 presents the Level 2 comparison of the EPCs with the ecological soil screening values. The EPC represents the lower of either the 95% UCL of the mean soil concentration or the maximum detected soil concentration in the surface soils (i.e., 0 to 0.5 ft bgs). Although the EPC to benchmark ratios are less than the maximum concentration to benchmark ratios, all metals continue to exceed their lowest ecological benchmark. Concentrations of the 13 metals that exceeded ecological benchmarks are evaluated further in the following subsections.

7.2.2.5.1.2.3 Reference Soils Comparison

A qualitative comparison between site soils and reference soils was performed for each of the 13 metals identified in the Level 1 analysis that had maximum detected concentrations greater than their respective benchmarks.

The results of the qualitative comparisons are presented in Table 7-41. The table prepared for Park presents the concentration of each of the 13 metals detected at each sample location and the maximum detected concentration in reference soils (see Table 7-46). The table also shows the ratio of the detected concentrations at Park to the maximum detected reference surface soil concentration for each sample. A ratio of 3.0 is the maximum threshold for which site concentrations are considered to be within the range of natural variability of the compound in soil. Note that qualitative comparisons for beryllium and thallium were conducted using the maximum quantitation limit rather than the maximum detected concentration because beryllium and thallium were not detected in the surface soils at the reference site.

The results of this qualitative comparison indicate that 10 of the 13 metals were present in concentrations that were within the 3x reference background maximum concentrations (i.e., within expected levels of natural variability). The potential ecological risk associated with these 10 metals (arsenic, beryllium, cadmium, chromium, mercury, nickel, selenium, silver, thallium, and zinc) may not be attributable to previous site activities, but rather may be due to naturally occurring concentrations of these metals in the soil. Antimony and copper were detected in soils at 3 of the 20 locations in Park at levels that were above background levels. Lead was detected at only one location at a level considered to be above naturally-occurring levels of lead in soils.

The results of the statistical comparison of the concentrations of inorganic constituents in Park land soils with those observed in reference soils are presented in Table 7-49. Based on this analysis, only the soil concentrations of antimony, copper and lead were found to be significantly higher than the levels of those same constituents in reference area soils. As described previously, antimony and copper were detected in soils at 3 of the 20 locations in Park at levels that were above reference soil levels. Lead was detected at only one location at a level considered to be above naturally-occurring levels of lead in soils.

7.2.2.5.1.2.4 Sediments at Park - Level 1

Table 7-42 presents a comparison of the detected sediment concentration and the ecological screening values for sediments for each compound for each sampled location for metals. These tables also present the ratio of the detected concentration for each of the analytes detected in Park sediments (for which ecological screening levels exist) with the lowest ecological screening benchmark evaluated. Shaded values indicate those screening levels that were exceeded.

A total of nine metals were detected in some or all of the sediment samples collected to characterize aquatic habitat. Of these detected chemicals, six metals were detected in sediment samples in concentrations that exceeded sediment screening values: cadmium, chromium, copper, lead, mercury, and selenium.

7.2.2.5.1.2.5 Sediments at Park - Level 2

The Level 2 analysis (i.e., a comparison of EPCs with ecological benchmarks for sediments) was not performed because sediment samples were evaluated independently.

7.2.2.5.1.2.6 Qualitative Reference Sediments Comparison

A qualitative comparison between Park sediments and reference sediment concentrations is provided here for the metals that exceeded ecological screening values at the site. This reference comparison is presented in tabular format in Table 7-43. As in the quantitative reference comparison presented for soils, ratios of the sample concentration to the reference sediment maximum concentration were calculated. Ratios less than 3 are considered to fall within the natural range of metals in sediments.

Of the six metals evaluated, four were present in concentrations in Park sediments that fall within the background threshold. The potential ecological risk associated with these four metals (cadmium, copper, lead, and selenium) may not be attributable to previous site activities. Because these concentrations fall within naturally occurring levels of these metals in the reference sediment, ecological risk associated with exposure to these metals is not expected to be different than that of background levels. Because chromium and mercury were not detected in reference sediments, site concentrations could not be compared to background threshold levels.

7.2.2.5.1.2.7 Surface Water at Park - Level 1

Tables 7-44 presents a comparison of the detected surface water concentration and the ecological screening values for surface water for each metal for each sampled location. These tables also present the ratio of the detected concentration for each of the analytes detected in Park surface water (for which ecological screening levels exist) with the lowest ecological screening benchmark evaluated. Shaded values indicate those screening levels that were exceeded.

A total of five metals were detected in some or all of the surface water samples collected to characterize aquatic habitat. Of these detected chemicals, only lead was detected at a concentration in surface water samples that exceeded surface water screening values. Beryllium was present in surface water samples but did not have a surface water screening criterion available for comparison.

7.2.2.5.1.2.8 Surface Water at Park - Level 2

The Level 2 analysis was not performed because surface water samples were evaluated independently.

7.2.2.5.1.2.9 Qualitative Reference Surface Water Comparison

A qualitative comparison between Park surface water and reference surface water concentrations is provided here for lead which exceeded its ecological screening values at the site, and for beryllium for which screening criteria have not been developed. This reference comparison is presented in tabular format in Table 7-45. As in the quantitative reference comparison presented for soils, ratios of the sample concentration to the reference surface water maximum concentration were calculated. Ratios greater than 3 are considered to exceed the natural range of metals in surface water.

Of the two metals evaluated, one lead sample was present in concentrations in Park surface water that are above the 3x background threshold. Because beryllium was not detected in reference sediments, site concentrations could not be compared to background threshold levels.

7.2.2.5.2 Uncertainty Analysis

Virtually every step in a risk assessment involves numerous assumptions that contribute to the total uncertainty in the final evaluation of risk. The uncertainties that are incorporated in the risk assessment may result in an increase or decrease in the estimated potential for adverse ecological effects. When methodologies for this SLERA were selected, conservative, yet realistic approaches and values were used when specific information was available.

Uncertainties in ERAs may be identified as belonging to one or more of the four following categories: conceptual model formulation uncertainty, data and information uncertainty, natural variability (stochasticity), and modeling error. These are not discrete categories, and overlap does exist among them. EPA's *Framework for Ecological Risk Assessment* (EPA, 1992c) document provides a more detailed discussion of these generic uncertainty categories.

For this SLERA, uncertainties are classified as either "general" or "specific." General uncertainties refer to broad concerns that may affect the risk assessment process overall, whereas specific uncertainties refer to the uncertainty surrounding one or more specific measurement endpoints used in this risk analysis. General uncertainties have been grouped into two categories for discussion purposes: (1) media sampling variability, and (2) data evaluation and reduction. Specific uncertainties are discussed in a single category called guideline and benchmark comparison.

7.2.2.5.2.1 Media Sampling Variability

Media sampling variability relates to the uncertainty inherent in the nature of the sampling process and the heterogeneity of the environment. Media sampling uncertainty is affected by the following factors:

- Note that the results of this SI level screening assessment must also be placed in the perspective of the inherent and often conservative assumptions employed in this screening level analysis. For example, the location of soil samples was biased to obtain the highest levels of contaminants in soils in the TOAR. Consequently, it is expected that the actual chemical levels to which plants and animals would be exposed outside the sampled areas is significantly less than those represented by the biased samples.

- Soil samples collected at the site reflect the conditions at that exact point in space and time. Spatial and temporal variations in soil conditions (both physical and chemical conditions) are often observed on very small scales. Given the heterogeneity of the environment, sample size and location greatly affect the certainty associated with the estimation of exposure and the consequent effects.

- Detected concentrations of contaminants may not be indicative of bioavailable concentrations. Organic chemicals may bind to other substances in the soil, e.g., humic acids, making them less available for uptake. Metals in soil may be associated with various mineral complexes that regulate potential variability. These interactions, along with the interactions of the contaminant with other chemicals in the environment, may make the contaminant either more or less toxic to organisms than expected.

7.2.2.5.2.2 Data Evaluation and Reduction

Data evaluation and reduction uncertainty, the second category of general uncertainty, is due to the nature of the methodology used to evaluate contaminant data and due to assumptions made during the analysis. Uncertainty in data evaluation and reduction for this study derives from the following:

- The use of the SQL or one-half the reported SQL of data from samples in which a contaminant was not detected introduces uncertainty into the estimation of exposure concentrations. The true distribution of concentrations below the SQL is not known; therefore, assuming concentrations of one-half the SQL may over- or under-estimate actual contaminant levels.

- In the Level 1 analysis, the maximum concentration detected of a specific contaminant is compared with its respective ecological benchmark value. The use of the maximum detected concentration, compared with the use of the mean concentration, represents a highly conservative measure of exposure, and may over-estimate the potential risk.

- In the Level 2 analysis, soil samples were aggregated for each of the Game and Park areas. EPCs (95% UCLs of the mean) were developed from these data aggregations. This approach introduces some uncertainty into the assessment of exposure and consequent risk. The aggregation of data while appropriate for some wide-ranging terrestrial species, e.g., white-tailed deer, may not be appropriate for those species whose home ranges are quite small, e.g., deer mouse. For these species, it may be more appropriate to combine samples at a much smaller spatial scale.

- Soil concentrations of COPECs for which the EPC exceeded the ecological screening benchmark value were compared with soil concentrations from reference areas. This comparison with background assumes that the site soil conditions are nearly identical to the conditions where background soils were collected. Because soils are rarely truly homogeneous, a number of samples are collected to account for heterogeneity and to presumably bracket the natural variability in soil chemistry. Consequently, the strength of any background comparison reflects the degree of confidence with which this variability has been adequately described. Limitations in the collection of site-specific reference data may result in a data set that is not sufficiently robust to capture the breadth of variability in soil chemistry.

7.2.2.5.2.3 Guideline and Benchmarks Comparison

Because of the diversity of soil types, test species, chemical forms, and test procedures, it is not possible to estimate benchmarks that would constitute thresholds for toxic effects on all organisms under all environmental conditions.

The guidelines and benchmarks used in this study included EPA Region III BTAG soil benchmarks and toxicity benchmarks derived by ORNL for a variety of taxa including plants, earthworms, soil microorganisms, and avian and mammalian wildlife.

The use of these values for evaluating the potential impacts of reported contaminant concentrations in soil has the following associated uncertainties:

- Screening level benchmarks do not address possible synergistic, antagonistic, or additive effects of contaminant mixtures. The risk may be over- or under-estimated, depending on the interactions among the various chemicals present at the site.
- The use of screening level benchmarks does not consider chemicals for which there is little or no toxicological information available. Any risk associated with exposure to these chemicals is not estimated and, therefore, the total site risk may be under-estimated.
- The test conditions used in the toxicological studies used to develop chemical-specific screening level benchmarks may not match the conditions at the TOAR-FUDS, therefore, the benchmarks may over- or under-estimate risk at the TOAR-FUDS. Testing conditions may have differed from the TOAR-FUDS in the following ways:
  - The form in which a chemical was added to the medium in deriving the benchmark may not be representative of the form the chemical is found in at the site. This is particularly true where the metallic salts added for toxicity testing purposes enhance the bioavailability of the metal relative to the metal species present under equilibrium conditions (i.e., complexed or strongly bound forms present).
  - The soil conditions (type, pH, temperature, and percent total organic carbon [TOC]) in the studies from which the benchmarks were derived may not mimic those conditions found at the site.
  - Studies from which chemical-specific soil benchmarks were derived reflect the complex physicochemical processes and mineral complexes of the soil in which the study was conducted. It is unlikely that the specific nutrient and mineral compositions of these mixtures match the conditions at the site.

- The benchmarks used do not consider factors that influence chemical bioavailability (e.g., site-specific organic carbon concentrations, redox potential, soil pH). Particularly for metals, the use of total concentration, rather than an estimate of the bioavailable fraction, represents a conservative estimate of exposure, and may over-estimate risk. In addition, most toxicological benchmarks developed for metals are based on soluble salts. However, it is expected that soluble salts would most likely be quickly leached from soils either through rainfall infiltration to groundwater or surface runoff to surface waters. Consequently, it is unlikely that the form of the metal used in the toxicity study would occur to a significant degree in weathered soils.

- Different species of plants and animals exhibit varying degrees of sensitivity to chemical stressors. The species used to derive the screening benchmarks do not necessarily have the same sensitivities as those found at the site. Consequently, the risk to ecological receptors at the site may be over- or under-estimated.

- Target receptors were selected to represent a variety of organisms with similar feeding and behavioral strategies to those expected to occur on the site for avian and mammalian wildlife benchmarks. However, species-specific exposure within similar feeding groups may vary and may result in differing risk potential. Target receptors were selected with the intent of optimizing exposure and assuming that a significant portion of their life cycles was restricted to that area of contamination. The assumption that avian and mammalian target receptors may spend a significant portion of their life cycles at the site may be conservative and thus overestimate the risk.

- Numerous assumptions and uncertainties are associated with the dietary exposure modeling used to calculate avian and mammalian wildlife screening level benchmarks. Because site-specific information is not available for receptor species for the screening level assessment, assumptions are made regarding ingestion rates and frequency of exposure, among others. Uncertainties associated with default assumptions include the following:

  - Maximum food ingestion rates and average body weights are used to estimate exposure intakes for all target receptors. This approach will most likely over-estimate daily intake for breeding or immature mammalian and avian receptors.

  - It is assumed that 100% of the target receptor's diet derives from the affected site. Foraging territory is inversely related to prey abundance. Based on the number of areas of similar habitat in the vicinity of the site that also support prey species, the assumption most likely over-estimates risk to several of the target avian species.

  - Potential exposure is limited to the consumption of food and the incidental ingestion of soil. No current methodology is adequate to describe exposure through dermal exposure or inhalation. Dermal absorption and inhalation may be of particular concern for species that burrow, forage, or build nests on the ground surface. These pathways were not assessed; this may tend to under-estimate the risk.

- At the screening level stage, no assessment of apex predators (e.g., red-tail hawk, red fox) was conducted. Current approaches to estimating residual contaminant levels in prey items (e.g., white-footed mouse) are inadequate. The absence of this evaluation may tend to under-estimate risk. Note, however, that the home ranges of these predators are quite large (e.g., red fox – 245 to 1,235 acres) and the expected fraction of diet contributed by the site is expected to be small.

▪ Wildlife screening values developed by ORNL were based on the LOAELs of the selected toxicity studies. By definition, a LOAEL is the lowest dose of a chemical that produces statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and its appropriate control (Dourson and Stara, 1983). The LOAEL values were converted to NOAEL values by dividing by a factor of 10. Although the factor of 10 is a commonly applied conversion between LOAELs and NOAELs, it is felt to be an upper-bound estimate of the potential extrapolation. Comparisons of studies (McNamara, 1976; Weil and McCollister, 1963) for which NOAELs and LOAELs were provided, indicate that 96% of the chemicals evaluated for both rodent and non-rodent receptors had LOAEL/NOAEL ratios of five or less (Dourson and Stara, 1983). It is expected that a 10-fold extrapolation factor may over-estimate the potential ecological risk.

In addition to the overall uncertainties associated with screening benchmark comparisons just discussed, there are also uncertainties associated with specific benchmarks used in this SLERA. Note that much of this discussion is taken from the previously cited references for ORNL. The discussion is limited to those aspects of the toxicology that may significantly alter the conclusions of the risk assessment. Consequently, only those data deemed of "low confidence" by the study investigators are presented in the following paragraphs. This discussion is also limited to those chemicals whose concentrations exceeded screening level benchmarks and were three times higher than background concentrations.

Antimony

▪ The phytotoxicity benchmark for antimony (5 mg/kg) is based on a single study that reported unspecified toxic effects caused by antimony on plants grown in surface soil. ORNL expressed low confidence in this benchmark because limited data were used to develop this value (ORNL, 1997a).

▪ Confidence in the EPA Region III BTAG screening value for antimony (0.48 mg/kg) is low because a citation for the source of this information was not provided in the draft guidance (EPA, 1995c). This benchmark was the lowest ecological benchmark used to evaluate surface soils.

Copper

- Confidence in the EPA Region III screening value for copper (15 mg/kg) is moderate because the citation provided in the draft guidance references an oil and hazardous materials database prepared by EPA and National Institute of Health (NIH) for the value. The ecological receptor(s) or exposure pathway(s) used to develop the value were not provided. This benchmark was the lowest available ecological benchmark used in the SLERA.

- The ORNL mammal (37 mg/kg) and bird (51.5 mg/kg) NOAEL-based PRGs for copper are based on dietary exposure models. Refer to the discussion presented earlier in this subsection that describes the uncertainty associated with exposure model assumptions.

Lead

- ORNL expressed moderate confidence in the phytotoxicity benchmark developed for lead (50 mg/kg), and high confidence in the microbial processes benchmark (900 mg/kg) developed for lead.

- Confidence in the EPA Region III BTAG screening value for lead (0.01 mg/kg) is low because the draft guidance lists the ecological receptor (Japanese quail) used to develop the value, but does not cite the study from which the value was used. This benchmark was the lowest available ecological benchmark used in the SLERA.

- The ORNL mammal (74 mg/kg) and bird (4.05 mg/kg) NOAEL-based PRGs for lead are based on dietary exposure models. Refer to the discussion presented earlier in this subsection that describes the uncertainty associated with exposure model assumptions.

Explosives

- A number of the explosives are lacking ecological screening level benchmarks for all media evaluated herein. All samples analyzed for explosives were below the detection limits and the detection limits were below benchmarks for those explosives for which benchmarks were available. However, conclusive remarks regarding risk cannot be made for those explosives for which benchmarks were not available.

7.2.2.5.3 Ecological Significance

7.2.2.5.3.1 Game

Of the 13 metals detected in Game surface soils from the TOAR-FUDS site, 12 exceeded their lowest ecological benchmark in the Level 2 benchmark comparison. Of these, all but antimony, beryllium and lead were within naturally occurring level if these metals in soils based on both the

3x and the statistical background comparisons. However, antimony and lead were present in concentrations that exceeded background levels in only a single sample location. Based on these results, munitions constituents are not expected to pose a significant ecological risk to flora and fauna inhabiting the terrestrial habitats of Game.

A total of 12 metals were detected in Game sediment samples. Of these 12 metals, 7 were detected in sediment samples in concentrations that exceeded sediment screening values: arsenic, cadmium, chromium, copper, lead, mercury, and selenium. All were present in concentrations within levels expected to occur naturally in sediment.

A total of 10 metals were detected in Game surface water samples. Of these 10 chemicals, 3 were detected in surface water samples in concentrations that exceeded surface water screening values: cadmium, copper, and lead. Of these metals, all were present in concentrations in Game surface water that are within levels expected to occur naturally in surface water.

Based on the results of the comparison with ecological screening level values and comparison with background levels in surface water and sediment, munitions constituents are not expected to pose a significant ecological risk to aquatic flora and fauna of Game.

7.2.2.5.3.2 Park

All of the 13 detected metals in the Park surface soils from the TOAR-FUDS exceeded associated ecological benchmarks in the Level 2 comparison. However, only 3 of these 13 metals were present in concentrations that exceeded background levels based on both the 3x and the statistical comparisons. For these metals, individual locations exceeding the reference soil levels included antimony (3 sample locations), copper (3 sample locations), and lead (1 sample location). Based on these results, munitions constituents are not expected to pose a significant ecological risk to flora and fauna inhabiting the terrestrial habitats of Park.

All of the 13 detected metals in the Park surface soils from the TOAR-FUDS exceeded associated ecological benchmarks in the Level 2 comparison. However, only 3 of these 13 metals were present in concentrations that exceeded background levels including antimony (3 sample locations), copper (3 sample locations), and lead (1 sample location).

A total of nine metals were detected in Park sediment samples. Of these nine metals, six were detected in sediment samples in concentrations that exceeded sediment screening values: cadmium, chromium, copper, lead, mercury, and selenium. Of these metals, all were present in concentrations in Park sediments that are within levels that are expected to occur naturally in sediments.

A total of five metals were detected in Park surface water samples. Of these five metals, only lead was detected in surface water samples in concentrations that exceeded surface water screening values. Additionally, only lead was present in concentrations in Park surface water that are above the 3x background threshold.

In summary, based on the screening analysis performed herein, neither explosives nor metals were detected at concentrations in soils, sediments or surface water (with the possible exception of lead) in the TOAR-FUDS that are expected to pose an ecologically significant risk to plant and animal populations inhabiting these media. Although the surface water concentrations of lead at 5 of 6 sampling locations exceeded AWQC, several conservative assumptions were made in this analysis.

First, the freshwater chronic AWQC for lead of 0.54 ug/L is based on the available or dissolved concentration of lead in the water and based on a hardness of 25 mg $CaCO_3$/L. The surface water samples that were collected as part of the SI were not filtered and therefore represent both dissolved and particulate fractions of lead. Depending on the quantity of particulate mass that was incorporated in the samples, this may significantly overestimate the bio-available fraction to which aquatic organisms would be exposed. As such the comparison with AWQC may substantially overestimate the risk.

Also, surface water samples were collected in ponded waters in areas that were heavily wooded. In the absence of water contact with substrate rich in calcium and magnesium salts, as one might observe in flowing streams, and the presence of elevated levels of humic acids typical of areas of heavy leaf litter, the surface waters were observed to be of low hardness (< 20 mg/L $CaCO_3$) and are expected to be somewhat acidic. Waters with these characteristics generally lack the nutrient and trace metal chemistry to develop adequate plant growth to support significant aquatic communities.

Second, the criterion for lead used in this assessment was derived as described in *Guidelines for deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and their Uses* (EPA, 1986). Moreover, the chronic freshwater criterion for lead is based on toxicity data for the following taxa:

- Fish – 2 species.
- Invertebrates – 2 species.
- Algae – number of species not noted.

As there are no fish inhabiting the surface waters under investigation, inclusion of this taxon in setting a relevant value for assessment of lead toxicity in surface waters of the Game and Park land is inappropriate. Consequently, a search of toxicity data for invertebrate exposure to lead in water was conducted. It is expected that invertebrates (e.g., larval insects) represent the dominant faunal community of these waters. Toward that end, EPA's EcoTox Database was queried for aquatic toxicity data for lead. This query resulted in 2,205 records. These records were further parsed to include only those data for aquatic invertebrates. Based on this data query, the lowest concentrations of lead in surface water expected to be protective of reproduction, classically considered the most sensitive endpoint in aquatic toxicity testing, were found to be 101 ug/L (the No-Observed-Effect-Concentration (NOEC), 220 ug/L (the Lowest-Observed Effect Concentration (LOEC) and 89 ug/L Maximum Acceptable Toxicant Concentration (MATC). As none of the surface water samples had lead concentrations greater than the MATC, lead is not anticipated to pose a risk to aquatic fauna inhabiting the surface waters of the Park and Game Lands.

In summary, based on the screening analysis performed herein, neither explosives nor metals were detected at concentrations in soils, sediments or surface water in the TOAR-FUDS that are expected to pose an ecologically significant risk to plant and animal populations inhabiting these media.

Table 7-8
Soil Human Health Risk-Based Benchmarks,
TOAR-FUDS, Tobyhanna, PA

Chemical	EPA Region III Residential Soil[a] (mg/kg)		EPA Region III Industrial Soil[a] (mg/kg)		PADEP Act 2 Direct Contact MSCs[b] (Residential, 0-15 ft) (mg/kg)	PADEP Act 2 Direct Contact MSCs[b] (Non-Residential, 0-2 ft) (mg/kg)	PADEP Act 2 Soil to Groundwater MSCs[c] (Residential) (mg/kg)	PADEP Act 2 Soil to Groundwater MSCs[c] (Non-Residential) (mg/kg)
Organics[d]								
Acetone	7,039	N	91,980	N	10,000	10,000	41	110
4,4'-DDT	1.88	C	8.42	C	53	230	110	330
Explosives								
HMX	391	N	5,110	N	NBA	NBA	NBA	NBA
RDX	5.81	C	26.0	C	NBA	NBA	NBA	NBA
1,3,5-Trinitrobenzene	235	N	3,066	N	NBA	NBA	NBA	NBA
1,3-Dintrobenzene	0.78	N	10.2	N	22	280	0.049	0.049
Tetryl	78.2	N	1,022	N	NBA	NBA	NBA	NBA
Nitrobenzene	3.91	N	51.1	N	110	1,400	0.79	2.20
2,4,6-Trinitrotoluene	21.3	C	95.4	C	110	1,400	0.023	0.023
4-Amino-2,6-dinitrotoluene	1.56	N	20.4	N	NBA	NBA	NBA	NBA
2-Amino-4,6-dinitrotoluene	1.56	N	20.4	N	NBA	NBA	NBA	NBA
2,4-Dinitrotoluene[e]	0.94	C	4.20	C	58	260	0.05	0.20
2,6-Dinitrotoluene[e]	0.94	C	4.20	C	220	2,800	1.1	3.0
m-Nitrotoluene	156	N	2,044	N	NBA	NBA	NBA	NBA
o-Nitrotoluene	2.78	C	12.4	C	NBA	NBA	NBA	NBA
p-Nitrotoluene	37.6	C	168	C	NBA	NBA	NBA	NBA
Inorganics								
Antimony	3.13	N	40.9	N	88	1,100	27	27
Arsenic	0.43	C	1.91	C	12	53.0	150	150
Beryllium	15.6	N	204	N	440	5,600	320	320
Cadmium	7.82	N	102	N	47	210	38	38
Chromium	23.5	N	307	N	94	420	190	190
Copper	313	N	4,088	N	8,200	100,000	36,000	36,000
Lead[f]	400		NBA		500	1,000	450	450
Mercury	2.35	N	30.7	N	66	840	10	10
Nickel	156	N	2,044	N	4,400	56,000	650	650
Selenium	39.1	N	511	N	1,100	14,000	26	26
Silver	39.1	N	511	N	1,100	14,000	84	84
Thallium	0.55	N	7.15	N	15	200	14	14
Zinc	2,346	N	30,660	N	66,000	190,000	12,000	12,000

mg/kg = Milligrams per kilogram.
MSC = Medium-specific concentration.
NBA = No benchmark available.
[a]USEPA Region III RBC Table (10/19/04), Residential and Industrial Values.
[b] PADEP Act 2 MSCs - Direct Contact Numeric Values for Organic and Inorganic Substances in soil.
[c] PADEP Act 2 MSCs - Soil to Groundwater Numeric Values for Organic and Inorganic Substances in Soil; Used Aquifers, TDS less than or equal to 2500, Generic Values.
[d] Only the two organic chemicals (acetone and 4,4-DDT) detected in test pit samples are presented in this table for screening purposes.
[e] Dinitrotoluene mixture value was used for the EPA Region III Residential and Industrial Soil RBCs.
[f] EPA OSWER residential screening level for Lead.
C = Cancer effects at a target risk of 1.0E-06.
N = Noncancer effects, at a target hazard quotient of 0.1.

Table 7-9
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
TOAR-FUDS, Tobyhanna, PA

Scenario Timeframe: Future
Medium: Soil/Sediment
Exposure Medium: State Park and Gameland - Surface Soils and Sediments

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening (1)	Background Value (2)	Screening Toxicity Value (3) (N/C)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag (Y/N)	Rationale for Selection or Deletion (4)
Surface Soils and Sediments	2691-41-0	HMX	0.069	0.069	mg/kg	F2A-SS-4257-001	1/45	0.50-0.50	0.069	N/A	391 N	N/A	N/A	No	BSL
	7440-36-0	Antimony	0.45	10	mg/kg	T4-SS-4251-001	35/45	1.30-6.10	10.0	N/A	3.13 N	N/A	N/A	Yes	ASL
	7440-38-2	Arsenic	2.00	22.7	mg/kg	T1-SS-4257-003	45/45	-	22.7	N/A	0.43 C	N/A	N/A	Yes	ASL
	7440-41-7	Beryllium	0.055	1.7	mg/kg	F2-SS-4257-001	35/45	0.40-2.40	1.70	N/A	15.64 N	N/A	N/A	No	BSL
	7440-43-9	Cadmium	0.15	1.7	mg/kg	T3-SD-4252-001	29/45	0.63-0.99	1.70	N/A	7.82 N	N/A	N/A	No	BSL
	7440-47-3	Chromium	2.00	11.75	mg/kg	T11-SD-4252-001_AVG	45/45	-	11.8	N/A	23.5 N	N/A	N/A	No	BSL
	7440-50-8	Copper	1.60	167	mg/kg	F2A-SS-4257-002	45/45	-	167	N/A	313 N	N/A	N/A	No	BSL
	7439-92-1	Lead	15.7	611	mg/kg	T4-SS-4251-001	45/45	-	611	N/A	400	N/A	N/A	Yes	ASL
	7439-97-6	Mercury	0.051	0.47	mg/kg	F2-SS-4257-001	44/45	0.052-0.052	0.47	N/A	2.35 N	N/A	N/A	No	BSL
	7440-02-0	Nickel	1.00	13.5	mg/kg	F2-SS-4257-001	45/45	-	13.5	N/A	156.4 N	N/A	N/A	No	BSL
	7782-49-2	Selenium	0.38	4.7	mg/kg	F2-SS-4257-001	45/45	-	4.70	N/A	26.00	N/A	N/A	No	BSL
	7440-22-4	Silver	0.039	1.2	mg/kg	T6-SS-4259-001	29/45	0.50-3.10	1.20	N/A	39.1 N	N/A	N/A	No	NBA
	7440-28-0	Thallium	0.59	1.4	mg/kg	T6-SS-4259-001	9/45	1.00-6.10	1.40	N/A	0.55 N	N/A	N/A	Yes	ASL
	7440-66-6	Zinc	11	154	mg/kg	F2-SS-4257-001	45/45	-	154	N/A	2346 N	N/A	N/A	No	BSL

(1) Maximum concentration used for screening.
(2) To date, no background study has been completed.
(3) All compounds were screened against the lower value of residential soil risk-based screening concentration (RBSC), PA DEP soil MSCs, and PA DEP soil to groundwater MSCs,
(4) Rationale Codes:
Selection Reason: Above Screening Levels (ASL)
Deletion Reason: Essential Nutrient (NUT)
Below Screening Level (BSL)

Definitions:
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/To Be Considered
C = Carcinogenic
COPC = Chemical of Potential Concern
N = Non-Carcinogenic
N/A = Not Applicable
NA = Not available.

Table 7-10
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
TOAR-FUDS, Tobyhanna, PA

Scenario Timeframe: Future
Medium: Soil/Sediment
Exposure Medium: State Park Surface Soils and Sediments

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening (1)	Background Value (2)	Screening Toxicity Value (3) (N/C)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag (Y/N)	Rationale for Selection or Deletion (4)
State Park	2691-41-0	HMX	0.069	0.069	mg/kg	F2A-SS-4257-001	1/20	0.50-0.50	0.069	N/A	391 N	N/A	N/A	No	BSL
Surface Soils	7440-36-0	Antimony	0.57	10	mg/kg	T4-SS-4251-001	14/20	1.30-6.10	10.0	N/A	3.13 N	N/A	N/A	Yes	ASL
and Sediments	7440-38-2	Arsenic	2.00	22.7	mg/kg	T1-SS-4257-003	20/20	-	22.7	N/A	0.43 C	N/A	N/A	Yes	ASL
	7440-41-7	Beryllium	0.055	1.7	mg/kg	F2-SS-4257-001	11/20	0.40-2.40	1.70	N/A	15.64 N	N/A	N/A	No	BSL
	7440-43-9	Cadmium	0.27	1.7	mg/kg	T3-SD-4252-001	17/20	0.74-0.83	1.70	N/A	7.82 N	N/A	N/A	No	BSL
	7440-47-3	Chromium	2.20	11.6	mg/kg	F2-SS-4257-001	20/20	-	11.6	N/A	23.5 N	N/A	N/A	No	BSL
	7440-50-8	Copper	9.00	167	mg/kg	F2A-SS-4257-002	20/20	-	167	N/A	313 N	N/A	N/A	No	BSL
	7439-92-1	Lead	44.6	611	mg/kg	T4-SS-4251-001	20/20	-	611	N/A	400	N/A	N/A	Yes	ASL
	7439-97-6	Mercury	0.057	0.47	mg/kg	F2-SS-4257-001	20/20	-	0.47	N/A	2.35 N	N/A	N/A	No	BSL
	7440-02-0	Nickel	2.10	13.5	mg/kg	F2-SS-4257-001	20/20	-	13.5	N/A	156.4 N	N/A	N/A	No	BSL
	7782-49-2	Selenium	0.39	4.7	mg/kg	F2-SS-4257-001	20/20	-	4.70	N/A	26.00	N/A	N/A	No	BSL
	7440-22-4	Silver	0.047	0.85	mg/kg	F2-SS-4257-001	11/20	0.50-3.10	0.85	N/A	39.1 N	N/A	N/A	No	NBA
	7440-28-0	Thallium	0.7	0.88	mg/kg	T1-SS-4257-003	2/20	1.00-6.10	0.88	N/A	0.55 N	N/A	N/A	Yes	ASL
	7440-66-6	Zinc	13.3	154	mg/kg	F2-SS-4257-001	20/20	-	154	N/A	2346 N	N/A	N/A	No	BSL

(1) Maximum concentration used for screening.
(2) To date, no background study has been completed.
(3) All compounds were screened against the lower value of residential soil risk-based screening concentration (RBSC), PA DEP soil MSCs, and PA DEP soil to groundwater MSCs,
(4) Rationale Codes:
Selection Reason: Above Screening Levels (ASL)
Deletion Reason: Essential Nutrient (NUT)
Below Screening Level (BSL)

Definitions:
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/To Be Considered
C = Carcinogenic
COPC = Chemical of Potential Concern
N = Non-Carcinogenic
N/A = Not Applicable
NA = Not available.

Table 7-11
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
TOAR-FUDS, Tobyhanna, PA

Scenario Timeframe: Future
Medium: Soil/Sediment
Exposure Medium: Gameland Surface Soils and Sediments

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening (1)	Background Value (2)	Screening Toxicity Value (3) (N/C)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag (Y/N)	Rationale for Selection or Deletion (4)
Gameland Surface Soils and Sediments	7440-36-0	Antimony	0.45	7.6	mg/kg	T9-SS-4258-002	21/25	1.30-3.70	7.60	N/A	3.13 N	N/A	N/A	Yes	ASL
	7440-38-2	Arsenic	2.40	22.1	mg/kg	T6-SS-4259-001	25/25	-	22.1	N/A	0.43 C	N/A	N/A	Yes	ASL
	7440-41-7	Beryllium	0.17	0.99	mg/kg	T6-SS-4259-001	24/25	1.50-1.50	0.99	N/A	15.64 N	N/A	N/A	No	BSL
	7440-43-9	Cadmium	0.15	0.99	mg/kg	T6-SD-4252-001	12/25	0.63-0.99	0.99	N/A	7.82 N	N/A	N/A	No	BSL
	7440-47-3	Chromium	2.00	11.75	mg/kg	T11-SD-4252-001_AVG	25/25	-	11.8	N/A	23.5 N	N/A	N/A	No	BSL
	7440-50-8	Copper	1.60	33	mg/kg	T6-SS-4259-001	25/25	-	33	N/A	313 N	N/A	N/A	No	BSL
	7439-92-1	Lead	15.7	375	mg/kg	T6-SS-4259-001	25/25	-	375	N/A	400	N/A	N/A	No	BSL
	7439-97-6	Mercury	0.051	0.26	mg/kg	T6-SD-4252-001	24/25	0.052-0.052	0.26	N/A	2.35 N	N/A	N/A	No	BSL
	7440-02-0	Nickel	1.00	11.5	mg/kg	RA11-SD-4259-00	25/25	-	11.5	N/A	156.4 N	N/A	N/A	No	BSL
	7782-49-2	Selenium	0.38	2.3	mg/kg	T6-SS-4259-001	25/25	-	2.30	N/A	26.00	N/A	N/A	No	BSL
	7440-22-4	Silver	0.039	1.2	mg/kg	T6-SS-4259-001	18/25	0.64-1.80	1.20	N/A	39.1 N	N/A	N/A	No	NBA
	7440-28-0	Thallium	0.59	1.4	mg/kg	T6-SS-4259-001	7/25	1.30-3.70	1.40	N/A	0.55 N	N/A	N/A	Yes	ASL
	7440-66-6	Zinc	11	116	mg/kg	RA11-SD-4259-00	25/25	-	116	N/A	2346 N	N/A	N/A	No	BSL

(1) Maximum concentration used for screening.
(2) To date, no background study has been completed.
(3) All compounds were screened against the lower value of residential soil risk-based screening concentration (RBSC), PA DEP MSCs, and PA DEP soil to groundwater MSCs,
(4) Rationale Codes:
Selection Reason: Above Screening Levels (ASL)
Deletion Reason: Essential Nutrient (NUT)
Below Screening Level (BSL)

Definitions:
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/To Be Considered
C = Carcinogenic
COPC = Chemical of Potential Concern
N = Non-Carcinogenic
N/A = Not Applicable
NA = Not available.

Table 7-12
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
TOAR-FUDS, Tobyhanna, PA

Scenario Timeframe: Future
Medium: Soil
Exposure Medium: Test Pit Soils

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening (1)	Background Value (2)	Screening Toxicity Value (3) (N/C)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag (Y/N)	Rationale for Selection or Deletion (4)
	50-29-3	4,4'-DDT	0.00028	0.00028	mg/kg	TOAR-FP1-TP-4287-004	1/2	0.002-0.002	0.00028	N/A	1.88 C	N/A	N/A	No	BSL
	67-64-1	Acetone	0.091	0.091	mg/kg	TOAR-FP1-TP-4287-007	1/2	0.019-0.019	0.091	N/A	41	N/A	N/A	No	BSL
	7440-36-0	Antimony	0.43	2.7	mg/kg	TOAR-FP1-TP-4287-007	2/2	-	2.70	N/A	3.13 N	N/A	N/A	No	BSL
	7440-38-2	Arsenic	5.3	25.1	mg/kg	TOAR-FP1-TP-4287-004	2/2	-	25.1	N/A	0.43 C	N/A	N/A	Yes	ASL
	7440-41-7	Beryllium	0.2	0.5	mg/kg	TOAR-FP1-TP-4287-004	2/2	-	0.50	N/A	15.64 N	N/A	N/A	No	BSL
	7440-43-9	Cadmium	0.6	0.92	mg/kg	TOAR-FP1-TP-4287-004	2/2	-	0.92	N/A	7.82 N	N/A	N/A	No	BSL
	7440-47-3	Chromium	7	9.5	mg/kg	TOAR-FP1-TP-4287-004	2/2	-	9.50	N/A	23.5 N	N/A	N/A	No	BSL
	7440-50-8	Copper	12.9	98.8	mg/kg	TOAR-FP1-TP-4287-007	2/2	-	98.8	N/A	313 N	N/A	N/A	No	BSL
	7439-92-1	Lead	15.2	316	mg/kg	TOAR-FP1-TP-4287-007	2/2	-	316	N/A	400	N/A	N/A	No	BSL
	7439-97-6	Mercury	0.067	0.067	mg/kg	TOAR-FP1-TP-4287-007	1/2	0.039-0.039	0.067	N/A	2.35 N	N/A	N/A	No	BSL
	7440-02-0	Nickel	8.4	15.7	mg/kg	TOAR-FP1-TP-4287-004	2/2	-	15.7	N/A	156.4 N	N/A	N/A	No	BSL
	7782-49-2	Selenium	0.46	0.46	mg/kg	TOAR-FP1-TP-4287-004	1/2	0.580-0.580	0.46	N/A	26.00	N/A	N/A	No	BSL
	7440-22-4	Silver	0.065	0.11	mg/kg	TOAR-FP1-TP-4287-007	2/2	-	0.11	N/A	39.1 N	N/A	N/A	No	BSL
	7440-66-6	Zinc	50	72.5	mg/kg	TOAR-FP1-TP-4287-007	2/2	-	72.5	N/A	2346 N	N/A	N/A	No	BSL

(1) Maximum concentration used for screening.
(2) To date, no background study has been completed.
(3) All compounds were screened against the lower value of residential soil risk-based screening concentration (RBSC), PA DEP soil MSCs, and PA DEP soil to groundwater MSCs,
(4) Rationale Codes:
Selection Reason:
Deletion Reason:
Below Screening Level (BSL)

Definitions: ARAR/TBC = Applicable or Relevant and Appropriate Requirement/To Be Considered
C = Carcinogenic
COPC = Chemical of Potential Concern
N = Non-Carcinogenic
N/A = Not Applicable
NA = Not available.

TABLE 7-13
EXPOSURE POINT CONCENTRATION SUMMARY
REASONABLE MAXIMUM EXPOSURE
TOAR-FUDS, Tobyhanna, PA

Scenario Timeframe: Future
Medium: Soil/Sediment
Exposure Medium: State Park and Gameland - Surface Soils and Sediments

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL (1) (Distribution)	Maximum Concentration (Qualifier)	Exposure Point Concentration			
						Value	Units	Statistic	Rationale
Surface Soils and Sediments	Antimony	mg/kg	1.46	2.67 (NP)	10.0	2.67	mg/kg	95% UCL-NP	W-Test (1)
	Arsenic	mg/kg	6.66	9.91 (NP)	22.7	9.91	mg/kg	95% UCL-NP	W-Test (1)
	Lead	mg/kg	102	126 (T)	611	126	mg/kg	95% UCL-T	W-Test (2)
	Thallium	mg/kg	0.94	1.05 (N)	1.40	1.05	mg/kg	95% UCL-N	W-Test (3)

Statistics: Maximum Detected Value (Maximum); 95% UCL of Normal Data (95% UCL-N); 95% UCL of Transformed Data (95% UCL-T); 95% UCL of Nonp
Nondetects were included at half the sample quantitation limit.
The EPC is based on the lower of the 95% UCL and the maximum detected concentration.

Definitions: N = Normal
NP = Nonparametric
T = Transformed

(1) ProUCL indicates data are nonparametric (0.05). The 95% Chebyshev (Mean, Sd) UCL was the ProUCL recommendation.
(2) ProUCL indicates data are lognormal. The H-UCL was the ProUCL recommendation.
(3) ProUCL indicates data are normal. The Student's-t UCL was the ProUCL recommendation.

TABLE 7-14
EXPOSURE POINT CONCENTRATION SUMMARY
REASONABLE MAXIMUM EXPOSURE
TOAR-FUDS, Tobyhanna, PA

Scenario Timeframe: Future
Medium: Soil
Exposure Medium: State Park Surface Soils and Sediments

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL (1) (Distribution)	Maximum Concentration (Qualifier)	Exposure Point Concentration			
						Value	Units	Statistic	Rationale
Surface Soils and Sediments	Antimony	mg/kg	1.79	4.04 (NP)	10.0	4.04	mg/kg	95% UCL-NP	W-Test (1)
	Arsenic	mg/kg	6.94	9.14 (G)	22.7	9.14	mg/kg	95% UCL-G	W-Test (2)
	Lead	mg/kg	136	183 (G)	611	183	mg/kg	95% UCL-G	W-Test (2)
	Thallium	mg/kg	1.00	1.24 (N)	0.88	0.88	mg/kg	95% UCL-N	W-Test (3)

Statistics: Maximum Detected Value (Maximum); 95% UCL of Normal Data (95% UCL-N); 95% UCL of Transformed Data (95% UCL-T).
Nondetects were included at half the sample quantitation limit.
The EPC is based on the lower of the 95% UCL and the maximum detected concentration.

Definitions: G = Gamma
N = Normal
NP = Nonparametric

(1) ProUCL indicates data are nonparametric (0.05). The 95% Chebyshev (Mean, Sd) UCL was the ProUCL recommendation.
(2) ProUCL indicates data are gamma. The Approximate Gamma UCL was the ProUCL recommendation.
(3) ProUCL indicates data are normal. The Student's-t UCL was the ProUCL recommendation.

TABLE 7-15
EXPOSURE POINT CONCENTRATION SUMMARY
REASONABLE MAXIMUM EXPOSURE
TOAR-FUDS, Tobyhanna, PA

Scenario Timeframe: Future
Medium: Soil
Exposure Medium: Gameland Surface Soils and Sediments

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL (1) (Distribution)	Maximum Concentration (Qualifier)	Exposure Point Concentration			
						Value	Units	Statistic	Rationale
Surface Soils	Antimony	mg/kg	1.20	2.41 (NP)	7.60	2.41	mg/kg	95% UCL-NP	W-Test (1)
and Sediments	Arsenic	mg/kg	6.43	8.05 (N)	22.1	8.05	mg/kg	95% UCL-N	W-Test (3)
	Thallium	mg/kg	0.89	0.98 (G)	1.40	0.98	mg/kg	95% UCL-G	W-Test (2)

Statistics: Maximum Detected Value (Maximum); 95% UCL of Normal Data (95% UCL-N); 95% UCL of Transformed Data (95% UCL-T).
Nondetects were included at half the sample quantitation limit.
The EPC is based on the lower of the 95% UCL and the maximum detected concentration.

Definitions: G = Gamma
N = Normal
NP = Nonparametric

(1) ProUCL indicates data are nonparametric (0.05). The 95% Chebyshev (Mean, Sd) UCL was the ProUCL recommendation.
(2) ProUCL indicates data are gamma. The Approximate Gamma UCL was the ProUCL recommendation.
(3) ProUCL indicates data are normal. The Student's-t UCL was the ProUCL recommendation.

TABLE 7-16
EXPOSURE POINT CONCENTRATION SUMMARY
REASONABLE MAXIMUM EXPOSURE
TOAR-FUDS, Tobyhanna, PA

Scenario Timeframe: Future
Medium: Soil
Exposure Medium: Test Pit Soils

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL (1) (Distribution)	Maximum Concentration (Qualifier)	Exposure Point Concentration			
						Value	Units	Statistic	Rationale
Soils	Arsenic	mg/kg	15.2	NC	25.1	25.1	mg/kg	Maximum	NA

Statistics: Maximum Detected Value (Maximum); 95% UCL of Normal Data (95% UCL-N); 95% UCL of Transformed Data (95% UCL-T).
Nondetects were included at half the sample quantitation limit.
The EPC is based on the lower of the 95% UCL and the maximum detected concentration.

Definitions: NA = Not available, insufficient sample size.
NC = Not calculated due to insufficient sample size.

Table 7-17
Adult Lead Model for Older Child Recreational User Scenario
TOAR-FUDS, Tobyhanna, PA

Calculations of Preliminary Remediation Goals (PRGs)

U.S. EPA Technical Review Workgroup for Lead, Adult Lead Committee

Exposure Variable	PRG Equation[1] 1*	PRG Equation[1] 2**	Description of Exposure Variable	Units	Values for Nonresidential Exposure Scenario: Using Equation 1, GSDi = 1.8	Using Equation 1, GSDi = 2.1	Using Equation 2, GSDi = 1.8	Using Equation 2, GSDi = 2.1
$PbB_{fetal, 0.95}$	X	X	95^{th} percentile PbB in fetus	ug/dL	10	10	10	10
$R_{fetal/maternal}$	X	X	Fetal/maternal PbB ratio	--	0.9	0.9	0.9	0.9
BKSF	X	X	Biokinetic Slope Factor	ug/dL per ug/day	0.4	0.4	0.4	0.4
GSD_i	X	X	Geometric standard deviation PbB	--	1.89	2.1	1.8	2.1
PbB_0	X	X	Baseline PbB	ug/dL	1.7	2.0	2.0	2.0
IR_S	X		Soil ingestion rate (including soil-derived indoor dust)	g/day	0.10	0.050	--	--
IR_{S+D}		X	Total ingestion rate of outdoor soil and indoor dust	g/day	--	--	0.050	0.050
W_S		X	Weighting factor; fraction of IR_{S+D} ingested as outdoor soil	--	--	--	1.000	1.000
K_{SD}		X	Mass fraction of soil in dust	--	--	--	0.700	0.700
$AF_{S, D}$	X	X	Absorption fraction (same for soil and dust)	--	0.12	0.12	0.12	0.12
$EF_{S, D}$[2]	X	X	Exposure frequency (same for soil and dust)	days/yr	90	219	219	219
PRG			**Preliminary Remediation Goal**	**ppm**	**1,858**	**888**	**1,545**	**888**

[1] Equation 1 does not apportion exposure between soil and dust ingestion (excludes W_S, K_{SD}).
When $IR_S = IR_{S+D}$ and $W_S = 1.0$, the equations yield the same PRG.

[2] The averaging time (AT) is a fixed value of 365 days/yr.

***Equation 1, based on Eq. 4 in USEPA (1996).**

$$PRG = \frac{([PbB_{95}fetal/(R*(GSD_i^{1.645})])-PbB_0)*AT}{BKSF*(IR_S*AF_S*EF_S)}$$

****Equation 2, alternate approach based on Eq. 4 and Eq. A-19 in USEPA (1996).**

$$PRG = \frac{([PbB_{fetal,0.95}/(R*(GSD_i^{1.645})])-PbB_0)*AT}{BKSF*([(IR_{S+D})*AF_S*EF_S*W_S]+[K_{SD}*(IR_{S+D})*(1-W_S)*AF_D*EF_D])}$$

Source: U.S. EPA (1996). Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil

Table 7-18
Adult Lead Model for Park Ranger Scenario
TOAR-FUDS, Tobyhanna, PA

Calculations of Preliminary Remediation Goals (PRGs)

U.S. EPA Technical Review Workgroup for Lead, Adult Lead Committee

Exposure Variable	PRG Equation[1] 1*	PRG Equation[1] 2**	Description of Exposure Variable	Units	Values for Nonresidential Exposure Scenario: Using Equation 1, GSDi = 1.8	Using Equation 1, GSDi = 2.1	Using Equation 2, GSDi = 1.8	Using Equation 2, GSDi = 2.1
$PbB_{fetal, 0.95}$	X	X	95th percentile PbB in fetus	ug/dL	10	10	10	10
$R_{fetal/maternal}$	X	X	Fetal/maternal PbB ratio	--	0.9	0.9	0.9	0.9
BKSF	X	X	Biokinetic Slope Factor	ug/dL per ug/day	0.4	0.4	0.4	0.4
GSD_i	X	X	Geometric standard deviation PbB	--	1.89	2.1	1.8	2.1
PbB_0	X	X	Baseline PbB	ug/dL	1.7	2.0	2.0	2.0
IR_S	X		Soil ingestion rate (including soil-derived indoor dust)	g/day	0.10	0.050	--	--
IR_{S+D}		X	Total ingestion rate of outdoor soil and indoor dust	g/day	--	--	0.050	0.050
W_S		X	Weighting factor; fraction of IR_{S+D} ingested as outdoor soil	--	--	--	1.000	1.000
K_{SD}		X	Mass fraction of soil in dust	--	--	--	0.700	0.700
$AF_{S, D}$	X	X	Absorption fraction (same for soil and dust)	--	0.12	0.12	0.12	0.12
$EF_{S, D}$[2]	X	X	Exposure frequency (same for soil and dust)	days/yr	250	219	219	219
PRG			**Preliminary Remediation Goal**	**ppm**	**669**	**888**	**1,545**	**888**

[1] Equation 1 does not apportion exposure between soil and dust ingestion (excludes W_S, K_{SD}).
When $IR_S = IR_{S+D}$ and $W_S = 1.0$, the equations yield the same PRG.

[2] The averaging time (AT) is a fixed value of 365 days/yr.

***Equation 1, based on Eq. 4 in USEPA (1996).**

$$PRG = \frac{([PbB_{95}fetal/(R*(GSD_i^{1.645})])-PbB_0)*AT}{BKSF*(IR_S*AF_S*EF_S)}$$

****Equation 2, alternate approach based on Eq. 4 and Eq. A-19 in USEPA (1996).**

$$PRG = \frac{([PbB_{fetal,0.95}/(R*(GSD_i^{1.645})])-PbB_0)*AT}{BKSF*([(IR_{S+D})*AF_S*EF_S*W_S]+[K_{SD}*(IR_{S+D})*(1-W_S)*AF_D*EF_D])}$$

Source: U.S. EPA (1996). Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil

Table 7-19
Summary of Chemicals Detected in Background Surface Soils in Park and Game
TOAR-FUDS, Tobyhanna, PA

Chemical[a]	Frequency of Detection[a]	Range of Detected Concentrations (mg/kg)	Range of Sample Quantitation Limits[b] (mg/kg)	Arithmetic Mean Concentration[c] (mg/kg)	Standard Deviation[c] (mg/kg)	Data Distribution	Calculation Method	95% UCL of the Mean[c] (mg/kg)	Exposure Point Concentration[d] (mg/kg)
Metals									
Antimony	4 / 8	0.41 - 0.99	1.30 - 1.70	0.69	0.18	Normal	Student's-t UCL	0.81	0.81
Arsenic	8 / 8	2.80 - 8.80	NA	5.23	2.26	Normal	Student's-t UCL	6.74	6.74
Beryllium[e]	0 / 8	-	0.51 - 0.72	0.30	0.038	Normal	Student's-t UCL	0.33	0.33
Cadmium	8 / 8	0.31 - 1.1	NA	0.69	0.26	Normal	Student's-t UCL	0.86	0.86
Chromium	8 / 8	3.10 - 9.0	NA	5.24	2.14	Normal	Student's-t UCL	6.67	6.67
Copper	8 / 8	4.90 - 12.6	NA	8.82	2.87	Normal	Student's-t UCL	10.7	10.7
Lead	8 / 8	17.7 - 115	NA	56.4	32.5	Normal	Student's-t UCL	78.2	78.2
Mercury	8 / 8	0.07 - 0.19	NA	0.13	0.039	Normal	Student's-t UCL	0.15	0.15
Nickel	8 / 8	1.30 - 6.20	NA	3.19	1.57	Normal	Student's-t UCL	4.24	4.24
Selenium	8 / 8	0.57 - 1.90	NA	1.22	0.45	Normal	Student's-t UCL	1.52	1.52
Silver	8 / 8	0.30 - 1.10	NA	0.62	0.26	Normal	Student's-t UCL	0.79	0.79
Thallium[e]	0 / 8	-	1.30 - 1.80	0.76	0.09	Normal	Student's-t UCL	0.82	0.82
Zinc	8 / 8	14.1 - 61.8	NA	31.9	18.3	Normal	Student's-t UCL	44.1	44.1

[a] Number of sampling locations at which chemical was detected compared with total number of sampling locations; duplicates at a location were averaged and considered one sample.

[b] Based on nondetected samples.

[c] Nondetects were included at half the sample quantitation limit (EPA, 1989b, 1992).

[d] Based on the lower of the 95% UCL and the maximum detected concentration (EPA, 1989b).

[e] Although the sample quantitation limits for Beryllium and Thallium were high compared to the site data and most of the sample results were nondetect, the laboratory would have reported any detections down to the analyte method detection limits (MDLs), ranges being 0.048-0.25 mg/kg for Beryllium and 0.53-2.8 mg/kg for Thallium.

mg/kg = Milligrams per kilogram

UCL = Upper confidence limit

Table 7-20
Statistical Comparison of Site and
Reference Chemical Concentrations in Surface Soils
TOAR-FUDS, Tobyhanna, PA

Metal	Arithmetic Mean ± Standard Deviation State Park and Gameland Soils[a]	Arithmetic Mean ± Standard Deviation Background[a] (mg/kg)	Statistical Analysis[b] Result
Antimony	1.46 ± 1.85	0.69 ± 0.18	S
Arsenic	6.66 ± 5.00	5.23 ± 2.26	NS
Lead	102 ± 106	56.4 ± 32.5	NS
Thallium[c]	0.94 ± 0.46	0.76 ± 0.09	NS

[a] Nondetects were included at half the sample quantitation limit.
[b] Right-tailed Mann-Whitney U-Test at 95% confidence level.
[c] Thallium was not detected in background soils, therefore the detection limits were halved and their statistics are shown above.
NS = Not significantly different ($p > 0.05$)
S = Significantly different ($p < 0.05$)
mg/kg = Milligrams per kilogram

Table 7-21
Statistical Comparison of Park and
Reference Chemical Concentrations in Surface Soils
TOAR-FUDS, Tobyhanna, PA

Metal	Arithmetic Mean ± Standard Deviation State Park Soils[a] (mg/kg)	Arithmetic Mean ± Standard Deviation Background[a] (mg/kg)	Statistical Analysis[b] Result
Antimony	1.79 ± 2.31	0.69 ± 0.18	S
Arsenic	6.94 ± 5.45	5.23 ± 2.26	NS
Lead	136 ± 128	56.4 ± 32.5	S
Thallium[c]	1.00 ± 0.62	0.76 ± 0.09	NS

[a] Nondetects were included at half the sample quantitation limit.
[b] Right-tailed Mann-Whitney U-Test at 95% confidence level.
[c] Thallium was not detected in background soils, therefore the detection limits were halved and their statistics are shown above.
NS = Not significantly different ($p > 0.05$)
S = Significantly different ($p < 0.05$)
mg/kg = Milligrams per kilogram

Table 7-22
Statistical Comparison of Game and
Reference Chemical Concentrations in Surface Soils
TOAR-FUDS, Tobyhanna, PA

Metal	Arithmetic Mean ± Standard Deviation Gameland Soils[a] (mg/kg)	Arithmetic Mean ± Standard Deviation Background[a] (mg/kg)	Statistical Analysis[b] Result
Antimony	1.20 ± 1.39	0.69 ± 0.18	S
Arsenic	6.43 ± 4.72	5.23 ± 2.26	NS
Thallium[c]	0.89 ± 0.28	0.76 ± 0.09	NS

[a] Nondetects were included at half the sample quantitation limit.
[b] Right-tailed Mann-Whitney U-Test at 95% confidence level.
[c] Thallium was not detected in background soils, therefore the detection limits were halved and their statistics are shown above.
NS = Not significantly different ($p > 0.05$)
S = Significantly different ($p < 0.05$)
mg/kg = Milligrams per kilogram

Table 7-23
Terrestrial and Aquatic Assessment and Measurement Endpoints
TOAR-FUDS, Tobyhanna, PA

Receptor	Assessment Endpoint	Rationale for Selection	Measurement Endpoint
Terrestrial Plants	Plant growth/yield	Herbaceous plants are at the base of the food chain, providing energy and nutrient transfer from soil to herbivorous and omnivorous receptors. Herbaceous plants also provide habitat for small birds and mammals.	Comparisons of estimated chemical concentrations in soil with ecological benchmarks for effects on vegetation
Invertebrates	Growth, reproduction, or activity	Like herbaceous plants, invertebrates are also at the base of the food chain, providing energy and nutrient transfer from soil to omnivorous and carnivorous receptors. Invertebrates also contribute to the physical breakdown of detritus for microbial decomposition.	Comparisons of estimated chemical concentrations in soil with ecological benchmarks for effects on soil microorganisms and earthworms.
Omnivorous Birds	Survival, growth, or reproduction	Omnivores are important in nutrient and energy transfer from lower to higher trophic levels.	Comparisons of soil concentrations with avian toxicity reference values (NOAEL-based Wildlife Benchmarks for Birds)
Omnivorous Mammals	Survival, growth, or reproduction	Omnivores are important in nutrient and energy transfer from lower to higher trophic levels.	Comparisons of soil concentrations with mammalian toxicity reference values (NOAEL-based Wildlife Benchmarks for mammals)
Benthic invertebrate community	Survival, reproduction, growth and indigenous community composition	Benthic invertebrates are at the base of the food chain, providing energy and nutrient transfer from sediment to omnivorous and carnivorous receptors. Benthic invertebrates also contribute to the physical breakdown of detritus for microbial decomposition.	Comparisons of estimated chemical concentrations in sediment and surface water to criteria and guidance values.
Aquatic community (including phytoplankton, algae, aquatic vegetation, aquatic invertebrates, and fish)	Survival, reproduction, growth and indigenous community composition	The aquatic community engenders a variety of trophic levels, from producers (e.g., algae) to secondary and tertiary trophic levels (e.g., omnivorous and piscivorous fish). These individuals also are a forage base for avian and mammalian piscivores.	Comparisons of estimated chemical concentrations in surface water to criteria and guidance values

Table 7-24
Summary of Chemicals Detected in Surface Soils and Sediments in Game
TOAR-FUDS, Tobyhanna, PA

Chemical	Frequency of Detection[a]	Range of Detected Concentrations (mg/kg)	Range of Sample Quantitation Limits[b] (mg/kg)	Arithmetic Mean Concentration[c] (mg/kg)	Standard Deviation[c] (mg/kg)	Data Distribution	Calculation Method	95% UCL of the Mean[c] (mg/kg)	Exposure Point Concentration[d] (mg/kg)
Explosives									
1,3,5-Trinitrobenzene	0 / 25	-	0.25 - 0.25	0.13	---	---	---	---	---
1,3-Dinitrobenzene	0 / 25	-	0.25 - 0.25	0.13	---	---	---	---	---
2,4,6-Trinitrotoluene	0 / 25	-	0.25 - 0.25	0.13	---	---	---	---	---
2,4-Dinitrotoluene	0 / 25	-	0.25 - 0.25	0.13	---	---	---	---	---
2,6-Dinitrotoluene	0 / 25	-	0.25 - 0.25	0.13	---	---	---	---	---
2-Amino-4,6-Dinitrotoluene	0 / 25	-	0.25 - 0.25	0.13	---	---	---	---	---
2-Nitrotoluene	0 / 25	-	0.25 - 0.25	0.13	---	---	---	---	---
3-Nitrotoluene	0 / 25	-	0.25 - 0.25	0.13	---	---	---	---	---
4-Amino-2,6-Dinitrotoluene	0 / 25	-	0.25 - 0.25	0.13	---	---	---	---	---
4-Nitrotoluene	0 / 25	-	0.25 - 0.25	0.13	---	---	---	---	---
HMX	0 / 25	-	0.50 - 0.50	0.25	---	---	---	---	---
Nitrobenzene	0 / 25	-	0.25 - 0.25	0.13	---	---	---	---	---
RDX	0 / 25	-	0.50 - 0.50	0.25	---	---	---	---	---
Tetryl	0 / 25	-	0.65 - 0.65	0.33	---	---	---	---	---
Inorganics									
Antimony	21 / 25	0.45 - 7.60	1.30 - 3.70	1.20	1.39	Non-parametric	95% Chebyshev (Mean, Sd)	2.41	2.41
Arsenic	25 / 25	2.40 - 22.1	NA	6.43	4.72	Normal	Student's-t	8.05	8.05
Beryllium	24 / 25	0.17 - 0.99	1.50 - 1.50	0.48	0.21	Normal	Student's-t	0.56	0.56
Cadmium	12 / 25	0.15 - 0.99	0.63 - 0.99	0.39	0.19	Normal	Student's-t	0.46	0.46
Chromium	25 / 25	2.00 - 11.8	NA	6.26	2.70	Normal	Student's-t	7.18	7.18
Copper	25 / 25	1.60 - 33.0	NA	10.4	7.49	Lognormal	95% H-UCL	13.8	13.8
Lead	25 / 25	15.7 - 375	NA	73.6	77.4	Gamma	Approximate Gamma	97.9	97.9
Mercury	24 / 25	0.05 - 0.26	0.05 - 0.05	0.13	0.05	Normal	Student's-t	0.14	0.14
Nickel	25 / 25	1.00 - 11.5	NA	4.14	2.76	Gamma	Approximate Gamma	5.16	5.16
Selenium	25 / 25	0.38 - 2.30	NA	1.02	0.48	Normal	Student's-t	1.18	1.18
Silver	18 / 25	0.04 - 1.20	0.64 - 1.80	0.28	0.27	Gamma	Approximate Gamma	0.38	0.38
Thallium	7 / 25	0.59 - 1.40	1.30 - 3.70	0.89	0.28	Gamma	Approximate Gamma	0.98	0.98
Zinc	25 / 25	11.0 - 116	NA	33.2	26.1	Non-parametric	95% Chebyshev (Mean, Sd)	55.9	55.9

[a] Number of sampling locations at which chemical was detected compared with total number of sampling locations; duplicates at a location were averaged and considered one sample.
[b] Based on nondetected samples.
[c] Nondetects were included at half the sample quantitation limit (EPA, 1989b, 1992).
[d] Based on the lower of the 95% UCL and the maximum detected concentration (EPA, 1989b).
mg/kg = Milligrams per kilogram
UCL = Upper confidence limit

Table 7-25
Summary of Chemicals Detected in Sediments in Game
TOAR-FUDS, Tobyhanna, PA

Chemical[a]	Frequency of Detection[a]	Range of Detected Concentrations (mg/kg)	Range of Sample Quantitation Limits[b] (mg/kg)	Arithmetic Mean Concentration[c] (mg/kg)	Standard Deviation[c] (mg/kg)	Data Distribution	95% UCL of the Mean[c] (mg/kg)	Exposure Point Concentration[d] (mg/kg)
Explosives								
1,3,5-Trinitrobenzene	0 / 3	-	0.25 - 0.25	0.13	---	---	---	---
1,3-Dinitrobenzene	0 / 3	-	0.25 - 0.25	0.13	---	---	---	---
2,4,6-Trinitrotoluene	0 / 3	-	0.25 - 0.25	0.13	---	---	---	---
2,4-Dinitrotoluene	0 / 3	-	0.25 - 0.25	0.13	---	---	---	---
2,6-Dinitrotoluene	0 / 3	-	0.25 - 0.25	0.13	---	---	---	---
2-Amino-4,6-Dinitrotoluene	0 / 3	-	0.25 - 0.25	0.13	---	---	---	---
2-Nitrotoluene	0 / 3	-	0.25 - 0.25	0.13	---	---	---	---
3-Nitrotoluene	0 / 3	-	0.25 - 0.25	0.13	---	---	---	---
4-Amino-2,6-Dinitrotoluene	0 / 3	-	0.25 - 0.25	0.13	---	---	---	---
4-Nitrotoluene	0 / 3	-	0.25 - 0.25	0.13	---	---	---	---
HMX	0 / 3	-	0.50 - 0.50	0.25	---	---	---	---
Nitrobenzene	0 / 3	-	0.25 - 0.25	0.13	---	---	---	---
RDX	0 / 3	-	0.50 - 0.50	0.25	---	---	---	---
Tetryl	0 / 3	-	0.65 - 0.65	0.33	---	---	---	---
Inorganics								
Antimony	1 / 3	0.63 - 0.63	1.30 - 3.70	1.04	0.70	ND	NC	0.63
Arsenic	3 / 3	2.80 - 6.20	NA	4.53	1.70	ND	NC	6.20
Beryllium	2 / 3	0.17 - 0.97	1.50 - 1.50	0.63	0.41	ND	NC	0.97
Cadmium	3 / 3	0.57 - 0.99	NA	0.74	0.22	ND	NC	0.99
Chromium	3 / 3	3.70 - 11.75	NA	7.02	4.21	ND	NC	11.8
Copper	3 / 3	1.60 - 20.1	NA	10.7	9.25	ND	NC	20.1
Lead	3 / 3	15.7 - 80.1	NA	39.7	35.2	ND	NC	80.1
Mercury	2 / 3	0.12 - 0.26	0.05 - 0.05	0.14	0.12	ND	NC	0.26
Nickel	3 / 3	6.80 - 11.5	NA	8.93	2.38	ND	NC	11.5
Selenium	3 / 3	0.44 - 1.10	NA	0.73	0.34	ND	NC	1.10
Silver	1 / 3	0.52 - 0.52	0.65 - 1.80	0.58	0.29	ND	NC	0.52
Zinc	3 / 3	30.7 - 116	NA	70.3	43.0	ND	NC	116

[a] Number of sampling locations at which chemical was detected compared with total number of sampling locations; duplicates at a location were averaged and considered one sample.
[b] Based on nondetected samples.
[c] Nondetects were included at half the sample quantitation limit (EPA, 1989b, 1992).
[d] Based on the lower of the 95% UCL and the maximum detected concentration (EPA, 1989b).
mg/kg = Milligrams per kilogram
NC = Not calculated due to insufficient sample size.
ND = Not determined due to insufficient sample size.
UCL = Upper confidence limit

Table 7-26
Summary of Chemicals Detected in Surface Water in Game
TOAR-FUDS, Tobyhanna, PA

Chemical[a]	Frequency of Detection[a]	Range of Detected Concentrations (mg/L)	Range of Sample Quantitation Limits[b] (mg/L)	Arithmetic Mean Concentration[c] (mg/L)	Standard Deviation[c] (mg/L)	Data Distribution	95% UCL of the Mean[c] (mg/L)	Exposure Point Concentration[d] (mg/L)
Explosives								
1,3,5-Trinitrobenzene	0 / 3	-	0.00020 - 0.00020	0.00010	---	---	---	---
1,3-Dinitrobenzene	0 / 3	-	0.00020 - 0.00020	0.00010	---	---	---	---
2,4,6-Trinitrotoluene	0 / 3	-	0.00020 - 0.00020	0.00010	---	---	---	---
2,4-Dinitrotoluene	0 / 3	-	0.00020 - 0.00020	0.00010	---	---	---	---
2,6-Dinitrotoluene	0 / 3	-	0.00020 - 0.00020	0.00010	---	---	---	---
2-Amino-4,6-Dinitrotoluene	0 / 3	-	0.00020 - 0.00020	0.00010	---	---	---	---
2-Nitrotoluene	0 / 3	-	0.00020 - 0.00020	0.00010	---	---	---	---
3-Nitrotoluene	0 / 3	-	0.00020 - 0.00020	0.00010	---	---	---	---
4-Amino-2,6-Dinitrotoluene	0 / 3	-	0.00020 - 0.00020	0.00010	---	---	---	---
4-Nitrotoluene	0 / 3	-	0.00020 - 0.00020	0.00010	---	---	---	---
HMX	0 / 3	-	0.00050 - 0.00050	0.00025	---	---	---	---
Nitrobenzene	0 / 3	-	0.00020 - 0.00020	0.00010	---	---	---	---
RDX	0 / 3	-	0.00050 - 0.00050	0.00025	---	---	---	---
Tetryl	0 / 3	-	0.00020 - 0.00020	0.00010	---	---	---	---
Inorganics								
Antimony	0 / 3	-	0.0100 - 0.0100	0.0050	---	---	---	---
Arsenic	1 / 3	0.0054 - 0.0054	0.0100 - 0.0100	0.0051	0.0002	ND	NC	0.0054
Beryllium	1 / 3	0.0016 - 0.0016	0.0040 - 0.0040	0.0019	0.0002	ND	NC	0.0016
Cadmium	1 / 3	0.0010 - 0.0010	0.0050 - 0.0050	0.0020	0.0009	ND	NC	0.0010
Chromium	1 / 3	0.0033 - 0.0033	0.0050 - 0.0050	0.0028	0.0004	ND	NC	0.0033
Copper	2 / 3	0.0039 - 0.012	0.0250 - 0.0250	0.0093	0.0047	ND	NC	0.012
Lead	2 / 3	0.0097 - 0.032	0.0030 - 0.0030	0.014	0.016	ND	NC	0.032
Mercury	1 / 3	0.0001 - 0.0001	0.0002 - 0.0002	0.0001	0.0000	ND	NC	0.0001
Nickel	2 / 3	0.0026 - 0.0032	0.040 - 0.040	0.0086	0.0099	ND	NC	0.0032
Selenium	0 / 3	-	0.0050 - 0.0050	0.0025	---	---	---	---
Silver	1 / 3	0.0003 - 0.0003	0.0050 - 0.0050	0.0018	0.0013	ND	NC	0.0003
Thallium	0 / 3	-	0.010 - 0.010	0.0050	---	---	---	---
Zinc	3 / 3	0.0070 - 0.024	NA	0.014	0.0089	ND	NC	0.024

[a] Number of sampling locations at which chemical was detected compared with total number of sampling locations; duplicates at a location were averaged and considered one sample.
[b] Based on nondetected samples.
[c] Nondetects were included at half the sample quantitation limit (EPA, 1989b, 1992).
[d] Based on the lower of the 95% UCL and the maximum detected concentration (EPA, 1989b).
mg/L = Milligrams per liter
NC = Not calculated due to insufficient sample size.
ND = Not determined due to insufficient sample size.
UCL = Upper confidence limit

Table 7-27
Summary of Chemicals Detected in Surface Soils and Sediments in Park
TOAR-FUDS, Tobyhanna, PA

Chemical	Frequency of Detection[a]	Range of Detected Concentrations (mg/kg)	Range of Sample Quantitation Limits[b] (mg/kg)	Arithmetic Mean Concentration[c] (mg/kg)	Standard Deviation[c] (mg/kg)	Data Distribution	Calculation Method	95% UCL of the Mean[c] (mg/kg)	Exposure Point Concentration[d] (mg/kg)
Explosives									
1,3,5-Trinitrobenzene	0 / 20	-	0.25 - 0.25	0.13	---	---	---	---	---
1,3-Dinitrobenzene	0 / 20	-	0.25 - 0.25	0.13	---	---	---	---	---
2,4,6-Trinitrotoluene	0 / 20	-	0.25 - 0.25	0.13	---	---	---	---	---
2,4-Dinitrotoluene	0 / 20	-	0.25 - 0.25	0.13	---	---	---	---	---
2,6-Dinitrotoluene	0 / 20	-	0.25 - 0.25	0.13	---	---	---	---	---
2-Amino-4,6-Dinitrotoluene	0 / 20	-	0.25 - 0.25	0.13	---	---	---	---	---
2-Nitrotoluene	0 / 20	-	0.25 - 0.25	0.13	---	---	---	---	---
3-Nitrotoluene	0 / 20	-	0.25 - 0.25	0.13	---	---	---	---	---
4-Amino-2,6-Dinitrotoluene	0 / 20	-	0.25 - 0.25	0.13	---	---	---	---	---
4-Nitrotoluene	0 / 20	-	0.25 - 0.25	0.13	---	---	---	---	---
HMX	1 / 20	0.069 - 0.069	0.50 - 0.50	0.24	0.040	Normal	Student's-t	0.26	0.069
Nitrobenzene	0 / 20	-	0.25 - 0.25	0.13	---	---	---	---	---
RDX	0 / 20	-	0.50 - 0.50	0.25	---	---	---	---	---
Tetryl	0 / 20	-	0.65 - 0.65	0.33	---	---	---	---	---
Inorganics									
Antimony	14 / 20	0.57 - 10.0	1.30 - 6.10	1.79	2.31	Non-parametric	95% Chebyshev (Mean, Sd) UCL	4.04	4.04
Arsenic	20 / 20	2.00 - 22.7	NA	6.94	5.45	Gamma	Approximate Gamma	9.14	9.14
Beryllium	11 / 20	0.06 - 1.70	0.40 - 2.40	0.45	0.39	Lognormal	95% H-UCL	0.70	0.70
Cadmium	17 / 20	0.27 - 1.70	0.74 - 0.83	0.56	0.38	Normal	Student's-t	0.70	0.70
Chromium	20 / 20	2.20 - 11.6	NA	5.33	2.32	Normal	Student's-t	6.23	6.23
Copper	20 / 20	9.00 - 167	NA	24.8	34.9	Non-parametric	95% Chebyshev (Mean, Sd)	58.9	58.9
Lead	20 / 20	44.6 - 611	NA	136	128	Gamma	Approximate Gamma	183	183
Mercury	20 / 20	0.06 - 0.47	NA	0.15	0.09	Gamma	Approximate Gamma	0.19	0.19
Nickel	20 / 20	2.10 - 13.5	NA	4.13	2.64	Gamma	Approximate Gamma	5.07	5.07
Selenium	20 / 20	0.39 - 4.70	NA	1.21	0.89	Gamma	Approximate Gamma	1.52	1.52
Silver	11 / 20	0.05 - 0.85	0.50 - 3.10	0.35	0.37	Gamma	Approximate Gamma	0.51	0.51
Thallium	2 / 20	0.70 - 0.88	1.00 - 6.10	1.00	0.62	Normal	Student's-t	1.24	0.88
Zinc	20 / 20	13.30 - 154	NA	42.1	36.7	Non-parametric	95% Chebyshev (Mean, Sd)	77.9	77.9

[a] Number of sampling locations at which chemical was detected compared with total number of sampling locations; duplicates at a location were averaged and considered one sample.
[b] Based on nondetected samples.
[c] Nondetects were included at half the sample quantitation limit (EPA, 1989b, 1992).
[d] Based on the lower of the 95% UCL and the maximum detected concentration (EPA, 1989b).
mg/kg = Milligrams per kilogram
UCL = Upper confidence limit

Table 7-28
Summary of Chemicals Detected in Sediments in Park
TOAR-FUDS, Tobyhanna, PA

Chemical[a]	Frequency of Detection[a]	Range of Detected Concentrations (mg/kg)	Range of Sample Quantitation Limits[b] (mg/kg)	Arithmetic Mean Concentration[c] (mg/kg)	Standard Deviation[c] (mg/kg)	Data Distribution	95% UCL of the Mean[c] (mg/kg)	Exposure Point Concentration[d] (mg/kg)
Explosives								
1,3,5-Trinitrobenzene	0 / 2	-	0.25 - 0.25	0.13	---	---	---	---
1,3-Dinitrobenzene	0 / 2	-	0.25 - 0.25	0.13	---	---	---	---
2,4,6-Trinitrotoluene	0 / 2	-	0.25 - 0.25	0.13	---	---	---	---
2,4-Dinitrotoluene	0 / 2	-	0.25 - 0.25	0.13	---	---	---	---
2,6-Dinitrotoluene	0 / 2	-	0.25 - 0.25	0.13	---	---	---	---
2-Amino-4,6-Dinitrotoluene	0 / 2	-	0.25 - 0.25	0.13	---	---	---	---
2-Nitrotoluene	0 / 2	-	0.25 - 0.25	0.13	---	---	---	---
3-Nitrotoluene	0 / 2	-	0.25 - 0.25	0.13	---	---	---	---
4-Amino-2,6-Dinitrotoluene	0 / 2	-	0.25 - 0.25	0.13	---	---	---	---
4-Nitrotoluene	0 / 2	-	0.25 - 0.25	0.13	---	---	---	---
HMX	0 / 2	-	0.50 - 0.50	0.25	---	---	---	---
Nitrobenzene	0 / 2	-	0.25 - 0.25	0.13	---	---	---	---
RDX	0 / 2	-	0.50 - 0.50	0.25	---	---	---	---
Tetryl	0 / 2	-	0.65 - 0.65	0.33	---	---	---	---
Inorganics								
Antimony	0 / 2	-	3.70 - 6.10	2.45	---	---	---	---
Arsenic	2 / 2	2.20 - 4.10	NA	3.15	1.34	ND	NC	4.10
Beryllium	0 / 2	-	1.50 - 2.40	0.98	---	---	---	---
Cadmium	2 / 2	0.66 - 1.70	NA	1.18	0.74	ND	NC	1.70
Chromium	2 / 2	3.60 - 4.90	NA	4.25	0.92	ND	NC	4.90
Copper	2 / 2	9.00 - 31.5	NA	20.3	15.9	ND	NC	31.5
Lead	2 / 2	44.6 - 113	NA	78.8	48.4	ND	NC	113
Mercury	2 / 2	0.10 - 0.21	NA	0.16	0.08	ND	NC	0.21
Nickel	2 / 2	4.80 - 7.60	NA	6.20	1.98	ND	NC	7.60
Selenium	2 / 2	1.40 - 1.70	NA	1.55	0.21	ND	NC	1.70
Silver	0 / 2	-	1.80 - 3.10	1.23	---	---	---	---
Thallium	0 / 2	-	3.70 - 6.10	2.45	---	---	---	---
Zinc	2 / 2	32.0 - 104	NA	68.0	50.9	ND	NC	104

[a] Number of sampling locations at which chemical was detected compared with total number of sampling locations; duplicates at a location were averaged and considered one sample.
[b] Based on nondetected samples.
[c] Nondetects were included at half the sample quantitation limit (EPA, 1989b, 1992).
[d] Based on the lower of the 95% UCL and the maximum detected concentration (EPA, 1989b).
mg/kg = Milligrams per kilogram
NC = Not calculated due to insufficient sample size.
ND = Not determined due to insufficient sample size.
UCL = Upper confidence limit

Table 7-29
Summary of Chemicals Detected in Surface Water in Park
TOAR-FUDS, Tobyhanna, PA

Chemical[a]	Frequency of Detection[a]	Range of Detected Concentrations (mg/L)	Range of Sample Quantitation Limits[b] (mg/L)	Arithmetic Mean Concentration[c] (mg/L)	Standard Deviation[c] (mg/L)	Data Distribution	95% UCL of the Mean[c] (mg/L)	Exposure Point Concentration[d] (mg/L)
Explosives								
1,3,5-Trinitrobenzene	0 / 2	-	2.00E-04 - 2.00E-04	1.00E-04	---	---	---	---
1,3-Dinitrobenzene	0 / 2	-	2.00E-04 - 2.00E-04	1.00E-04	---	---	---	---
2,4,6-Trinitrotoluene	0 / 2	-	2.00E-04 - 2.00E-04	1.00E-04	---	---	---	---
2,4-Dinitrotoluene	0 / 2	-	2.00E-04 - 2.00E-04	1.00E-04	---	---	---	---
2,6-Dinitrotoluene	0 / 2	-	2.00E-04 - 2.00E-04	1.00E-04	---	---	---	---
2-Amino-4,6-Dinitrotoluene	0 / 2	-	2.00E-04 - 2.00E-04	1.00E-04	---	---	---	---
2-Nitrotoluene	0 / 2	-	2.00E-04 - 2.00E-04	1.00E-04	---	---	---	---
3-Nitrotoluene	0 / 2	-	2.00E-04 - 2.00E-04	1.00E-04	---	---	---	---
4-Amino-2,6-Dinitrotoluene	0 / 2	-	2.00E-04 - 2.00E-04	1.00E-04	---	---	---	---
4-Nitrotoluene	0 / 2	-	2.00E-04 - 2.00E-04	1.00E-04	---	---	---	---
HMX	0 / 2	-	5.00E-04 - 5.00E-04	2.50E-04	---	---	---	---
Nitrobenzene	0 / 2	-	2.00E-04 - 2.00E-04	1.00E-04	---	---	---	---
RDX	0 / 2	-	5.00E-04 - 5.00E-04	2.50E-04	---	---	---	---
Tetryl	0 / 2	-	2.00E-04 - 2.00E-04	1.00E-04	---	---	---	---
Inorganics								
Antimony	0 / 2	-	1.00E-02 - 1.00E-02	5.00E-03	---	---	---	---
Arsenic	0 / 2	-	1.00E-02 - 1.00E-02	5.00E-03	---	---	---	---
Beryllium	0 / 2	-	4.00E-03 - 4.00E-03	2.00E-03	---	---	---	---
Cadmium	0 / 2	-	5.00E-03 - 5.00E-03	2.50E-03	---	---	---	---
Chromium	0 / 2	-	5.00E-03 - 5.00E-03	2.50E-03	---	---	---	---
Copper	2 / 2	1.90E-03 - 6.40E-03	NA	4.15E-03	3.18E-03	ND	NC	6.40E-03
Lead	2 / 2	4.60E-03 - 2.70E-02	NA	1.58E-02	1.58E-02	ND	NC	2.70E-02
Mercury	0 / 2	-	2.00E-04 - 2.00E-04	1.00E-04	---	---	---	---
Nickel	1 / 2	1.40E-03 - 1.40E-03	4.00E-02 - 4.00E-02	1.07E-02	1.32E-02	ND	NC	1.40E-03
Selenium	1 / 2	3.80E-03 - 3.80E-03	5.00E-03 - 5.00E-03	3.15E-03	9.19E-04	ND	NC	3.80E-03
Silver	0 / 2	-	5.00E-03 - 5.00E-03	2.50E-03	---	---	---	---
Thallium	0 / 2	-	1.00E-02 - 1.00E-02	5.00E-03	---	---	---	---
Zinc	2 / 2	1.21E-02 - 2.29E-02	NA	1.75E-02	7.64E-03	ND	NC	2.29E-02

[a] Number of sampling locations at which chemical was detected compared with total number of sampling locations; duplicates at a location were averaged and considered one sample.

[b] Based on nondetected samples.

[c] Nondetects were included at half the sample quantitation limit (EPA, 1989b, 1992).

[d] Based on the lower of the 95% UCL and the maximum detected concentration (EPA, 1989b).

mg/L = Milligrams per liter

NC = Not calculated due to insufficient sample size.

ND = Not determined due to insufficient sample size.

UCL = Upper confidence limit

Table 7-30
Level 1 SLERA
Comparison of Maximum Detected Soil Concentrations with Ecological Benchmarks in Game
TOAR-FUDS, Tobyhanna, PA

Chemical	Maximum Detected Concentration (mg/kg)	Sample ID	Oak Ridge National Laboratory Benchmarks: Phytotoxicity (mg/kg)a	Oak Ridge: Earthworm Toxicity (mg/kg)b	Oak Ridge: Microorganisms/ Microbial Processes Toxicity (mg/kg)b	Oak Ridge: NOAEL-based Wildlife Benchmarks: Mammals (mg/kg)c	Oak Ridge: NOAEL-based Wildlife Benchmarks: Birds (mg/kg)c	Region III BTAG Benchmarks (mg/kg)d	Ecological SSLs[e]: Plants (mg/kg)	Ecological SSLs: Soil Invertebrates (mg/kg)	Ecological SSLs: Mammals (mg/kg)	Ecological SSLs: Birds (mg/kg)	Lowest Ecological Benchmark (mg/kg)	Ratio of Maximum Detected Conc. to Lowest Benchmark
Inorganics														
Antimony	7.6	T9-SS-4258-002	5.0	NBA	NBA	NBA	NBA	0.48 [g]	NA	78	0.27	NA	0.27	28.1
Arsenic	22.1	T6-SS-4259-001	10	60	100	0.99	10.2	328 [g]	18	NA	46	43	0.99	22.3
Beryllium	0.99	T6-SS-4259-001	10	NBA	NBA	NBA	NBA	0.02 [g]	NA	40	21	NA	0.020	49.5
Cadmium	0.99	T6-SD-4252-001	4.0	20	20	0.6	0.42	2.5 [g]	32	140	0.36	0.77	0.36	2.75
Chromium	11.8	T11-SD-4252-001_AVG	1.0	0.4	10	11	1.61	0.0075 [h]	NA	NA	81 [i]	26 [j]	0.0075	1,567
Copper	33	T6-SS-4259-001	100	50	100	37	51.5	15 [g]	NA	NA	NA	NA	15	2.20
Lead	375	T6-SS-4259-001	50	500	900	74	4.05	0.01 [h]	120	1700	56	11	0.010	37,500
Mercury	0.26	T6-SD-4252-001	0.3	0.1	30	0.015	0.000051	0.058 [f]	NA	NA	NA	NA	0.000051	5,098
Nickel	11.5	RA11-SD-4259-00	30	200	90	24.6	12.1	2.0 [g]	NA	NA	NA	NA	2.0	5.75
Selenium	2.3	T6-SS-4259-001	1.0	70	100	0.021	42	1.8 [f]	NA	NA	NA	NA	0.021	110
Silver	1.2	T6-SS-4259-001	2.0	NBA	50	NBA	NBA	0.0000098 [g]	NA	NA	NA	NA	0.0000098	122,449
Thallium	1.4	T6-SS-4259-001	1.0	NBA	NBA	0.21	NBA	0.001 [g]	NA	NA	NA	NA	0.0010	1,400
Zinc	116	RA11-SD-4259-00	50	200	100	160	0.85	10 [g]	NA	NA	NA	NA	0.85	136

Notes:
(1) Shading indicates the maximum detection exceeds the benchmark.
Definitions:
mg/kg = Milligrams per kilogram.
NBA = No benchmark available.
NOAEL = No observed adverse effects level.
[a] ORNL, 1997a. Oak Ridge National Laboratories *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision.*
[b] ORNL, 1997b. Oak Ridge National Laboratories *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision* .
[c] ORNL, 1997c. Oak Ridge National Laboratories *Preliminary Remediation Goals (PRGs) for Ecological Endpoints.* Adjusted LOAEL values in guidance by a factor of 10 to convert to NOAELs.
[d] EPA, 1995. *Region III Biological Technical Assistance Group Screening Levels - Draft.* September, 1995.
[e] EPA, 2005. *Ecological Soil Screening Levels.*
[f] Region III BTAG soil screening level for flora and fauna.
[g] Region III BTAG soil screening level for flora.
[h] Region III BTAG soil screening level for fauna.
[i] Chromium VI value used for mammalian SSL.
[j] Chromium III value used for avian SSL.

Table 7-31
Level 2 SLERA
Comparison of Exposure Point Concentrations with Ecological Benchmarks in Game
TOAR-FUDS, Tobyhanna, PA

Chemical	Exposure Point Concentration (mg/kg)	Oak Ridge National Laboratory Benchmarks: Phytotoxicity (mg/kg)[a]	Oak Ridge National Laboratory Benchmarks: Earthworm Toxicity (mg/kg)[b]	Oak Ridge National Laboratory Benchmarks: Microorganisms/ Microbial Processes Toxicity (mg/kg)[b]	Oak Ridge National Laboratory Benchmarks: NOAEL-based Wildlife Benchmarks: Mammals (mg/kg)[c]	Oak Ridge National Laboratory Benchmarks: NOAEL-based Wildlife Benchmarks: Birds (mg/kg)[c]	Region III BTAG Benchmarks (mg/kg)[d]	Ecological SSLs[e]: Plants (mg/kg)	Ecological SSLs[e]: Soil Invertebrates (mg/kg)	Ecological SSLs[e]: Mammals (mg/kg)	Ecological SSLs[e]: Birds (mg/kg)	Lowest Ecological Benchmark (mg/kg)	Ratio of EPC to Lowest Benchmark
Inorganics													
Antimony	2.41	5.0	NBA	NBA	NBA	NBA	0.48 [g]	NA	78	0.27	NA	0.27	8.92
Arsenic	8.05	10	60	100	0.99	10.2	328 [g]	18	NA	46	43	0.99	8.13
Beryllium	0.56	10	NBA	NBA	NBA	NBA	0.02 [g]	NA	40	21	NA	0.02	27.9
Cadmium	0.46	4.0	20	20	0.6	0.42	2.5 [g]	32	140	0.36	0.77	0.36	1.27
Chromium	7.18	1.0	0.4	10	11	1.61	0.0075 [h]	NA	NA	81 [i]	26 [j]	0.0075	958
Copper	13.8	100	50	100	37	51.5	15 [g]	NA	NA	NA	NA	15	0.92
Lead	97.9	50	500	900	74	4.05	0.01 [h]	120	1700	56	11	0.01	9,788
Mercury	0.14	0.3	0.1	30	0.015	0.000051	0.058 [f]	NA	NA	NA	NA	0.000051	2,836
Nickel	5.16	30	200	90	24.6	12.1	2.0 [g]	NA	NA	NA	NA	2.0	2.58
Selenium	1.18	1.0	70	100	0.021	42	1.8 [f]	NA	NA	NA	NA	0.021	56.2
Silver	0.38	2.0	NBA	50	NBA	NBA	0.0000098 [g]	NA	NA	NA	NA	0.0000098	38,745
Thallium	0.98	1.0	NBA	NBA	0.21	NBA	0.001 [g]	NA	NA	NA	NA	0.001	984
Zinc	55.9	50	200	100	160	0.85	10 [g]	NA	NA	NA	NA	0.85	65.7

Notes:
(1) Shading indicates the EPC exceeds the benchmark.
Definitions:
mg/kg = Milligrams per kilogram.
NBA = No benchmark available.
NOAEL = No observed adverse effects level.

[a] ORNL, 1997a. Oak Ridge National Laboratories. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision.*
[b] ORNL, 1997b. Oak Ridge National Laboratories. *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision*.
[c] ORNL, 1997c. Oak Ridge National Laboratories. *Preliminary Remediation Goals (PRGs) for Ecological Endpoints.* Adjusted LOAEL values in guidance by a factor of 10 to convert to NOAELs.
[d] EPA, 1995. *Region III Biological Technical Assistance Group Screening Levels - Draft.* September, 1995.
[e] EPA, 2005. *Ecological Soil Screening Levels.*
[f] Region III BTAG soil screening level for flora and fauna.
[g] Region III BTAG soil screening level for flora.
[h] Region III BTAG soil screening level for fauna.
[i] Chromium VI value used for mammalian SSL.
[j] Chromium III value used for avian SSL.

Table 7-32
Comparison of Metal Concentrations in Game with Reference Soil Concentrations[a]
TOAR-FUDS, Tobyhanna, PA

Chemical	Reference Surface Soils Max. Concentration[a] (mg/kg)	Game Site Concentrations F4-SS-4258-001 (mg/kg)	F5-SS-4257-001 (mg/kg)	RA11-SD-4259-00 (mg/kg)	T11-SD-4252-001_AVG (mg/kg)	T6-SD-4252-001 (mg/kg)	T10-SS-4258-002 (mg/kg)	T11-SS-4259-002 (mg/kg)	T6-SS-4259-002_AVG (mg/kg)
Metals									
Antimony	0.99	1.30	0.89	0.63	ND (1.30)[c]	ND (3.70)[c]	0.45	0.65	0.76
Arsenic	8.80	5.20	3.90	6.20	4.60	2.80	3.70	5.70	20.8
Beryllium[b]	0.72	0.79	0.54	0.97	0.17	ND (1.50)[c]	0.47	0.42	0.41
Cadmium	1.10	0.31	ND (0.99)[c]	0.65	0.57	0.99	ND (0.63)[c]	ND (0.67)[c]	ND (0.71)[c]
Chromium	9.00	4.60	3.90	3.70	11.8	5.60	6.00	6.80	9.35
Copper	12.6	10.9	7.30	1.60	10.5	20.1	9.00	10.2	11.1
Lead	115	45.5	28.5	23.4	15.7	80.1	23.8	63.4	106
Mercury	0.19	0.18	0.18	ND (0.052)[c]	0.12	0.26	0.062	0.097	0.15
Nickel	6.20	3.50	2.00	11.5	8.50	6.80	4.20	10.2	4.65
Selenium	1.90	1.90	1.20	0.64	0.44	1.10	0.38	0.69	1.25
Silver	1.10	0.26	0.21	0.52	ND (0.65)[c]	ND (1.80)[c]	0.039	0.087	0.14
Thallium[b]	1.80	ND (2.40)[c]	ND (2.00)[c]	ND (1.60)[c]	ND (1.30)[c]	ND (3.70)[c]	0.59	ND (1.30)[c]	ND (1.40)[c]
Zinc	61.8	26.3	18.1	116	30.7	64.1	23.4	25.0	26.4

Table 7-32
Comparison of Metal Concentrations in Game with Reference Soil Concentrations[a]
TOAR-FUDS, Tobyhanna, PA

Chemical	Reference Surface Soils Max. Concentration[a] (mg/kg)	Gameland Site Concentrations T7-SS-4258-001 (mg/kg)	T7-SS-4258-003_AVG (mg/kg)	T8-SS-4258-002 (mg/kg)	T9-SS-4258-001 (mg/kg)	T9-SS-4258-003 (mg/kg)	F4-SS-4258-002_AVG (mg/kg)	F5-SS-4257-002 (mg/kg)	T10-SS-4258-001 (mg/kg)
Metals									
Antimony	0.99	0.86	0.64	0.98	0.78	0.75	1.40	ND (1.90)[c]	0.61
Arsenic	8.80	6.70	4.25	7.80	6.90	5.30	5.70	2.40	5.60
Beryllium[b]	0.72	0.37	0.31	0.41	0.47	0.31	0.72	0.42	0.34
Cadmium	1.10	ND (0.70)[c]	ND (0.66)[c]	ND (0.85)[c]	0.27	ND (0.64)[c]	0.30	0.39	ND (0.65)[c]
Chromium	9.00	10.0	5.20	9.20	8.20	8.00	5.80	2.00	5.40
Copper	12.6	7.10	3.95	4.20	10.2	4.40	12.6	6.00	8.40
Lead	115	39.3	28.3	37.3	45.6	33.1	74.1	46.7	50.3
Mercury	0.19	0.16	0.077	0.12	0.12	0.093	0.19	0.085	0.10
Nickel	6.20	4.70	1.95	2.50	4.30	2.80	4.00	1.90	2.40
Selenium	1.90	0.93	1.03	0.99	1.50	0.41	1.55	0.67	1.00
Silver	1.10	0.084	ND (0.66)[c]	0.077	0.38	ND (0.64)[c]	0.12	0.098	0.14
Thallium[b]	1.80	1.10	0.83	ND (1.70)[c]	ND (1.50)[c]	0.64	ND (2.20)[c]	ND (1.90)[c]	0.91
Zinc	61.8	23.3	11.5	17.4	38.1	20.9	39.6	34.0	18.2

Table 7-32
Comparison of Metal Concentrations in Game with Reference Soil Concentrations[a]
TOAR-FUDS, Tobyhanna, PA

Chemical	Reference Surface Soils Max. Concentration[a] (mg/kg)	Gameland Site Concentrations T10-SS-4258-003 (mg/kg)	T11-SS-4259-001 (mg/kg)	T11-SS-4259-003 (mg/kg)	T6-SS-4259-001 (mg/kg)	T6-SS-4259-003 (mg/kg)	T7-SS-4258-002 (mg/kg)	T8-SS-4258-001 (mg/kg)	T8-SS-4258-003 (mg/kg)	T9-SS-4258-002 (mg/kg)
Metals										
Antimony	0.99	0.82	0.63	ND (1.30)[c]	1.50	0.98	0.74	1.00	1.90	7.60
Arsenic	8.80	3.60	4.50	4.20	22.1	6.70	6.40	6.10	3.90	5.80
Beryllium[b]	0.72	0.72	0.35	0.31	0.99	0.36	0.35	0.40	0.39	0.37
Cadmium	1.10	0.15	ND (0.72)[c]	ND (0.64)[c]	0.79	0.24	0.18	ND (0.67)[c]	0.25	ND (0.90)[c]
Chromium	9.00	3.90	4.70	3.40	9.30	3.10	6.50	11.4	3.60	5.00
Copper	12.6	8.10	7.40	4.40	33.0	10.8	10.1	31.3	9.70	7.70
Lead	115	67.7	39.0	23.4	375	187	87.5	56.0	197	66.3
Mercury	0.19	0.10	0.10	0.051	0.15	0.096	0.19	0.18	0.14	0.15
Nickel	6.20	2.50	1.60	1.00	7.60	2.40	4.20	4.10	2.30	1.90
Selenium	1.90	0.90	0.65	0.40	2.30	0.95	1.60	0.71	1.20	1.00
Silver	1.10	ND (0.93)[c]	0.14	ND (0.64)[c]	1.20	0.11	0.18	ND (0.67)[c]	0.21	0.12
Thallium[b]	1.80	ND (1.90)[c]	0.80	ND (1.30)[c]	1.40	ND (1.40)[c]	ND (1.60)[c]	ND (1.30)[c]	ND (1.70)[c]	ND (1.80)[c]
Zinc	61.8	18.0	18.2	11.0	107	26.6	40.7	20.2	26.7	27.7

Table 7-32
Comparison of Metal Concentrations in Game with Reference Soil Concentrations[a]
TOAR-FUDS, Tobyhanna, PA

Chemical	Reference Surface Soils Max. Concentration[a] (mg/kg)	Ratio of Site Soil to Reference Soil Concentration							
		F4-SS-4258-001	F5-SS-4257-001	RA11-SD-4259-00	T11-SD-4252-001_AVG	T6-SD-4252-001	T10-SS-4258-002	T11-SS-4259-002	T6-SS-4259-002_AVG
Metals									
Antimony	0.99	1.31	0.90	0.64	--- (ND)	--- (ND)	0.45	0.66	0.77
Arsenic	8.80	0.59	0.44	0.70	0.52	0.32	0.42	0.65	2.36
Beryllium[b]	0.72	1.10	0.75	1.35	0.24	--- (ND)	0.65	0.58	0.57
Cadmium	1.10	0.28	--- (ND)	0.59	0.51	0.90	--- (ND)	--- (ND)	--- (ND)
Chromium	9.00	0.51	0.43	0.41	1.31	0.62	0.67	0.76	1.04
Copper	12.6	0.87	0.58	0.13	0.83	1.60	0.71	0.81	0.88
Lead	115	0.40	0.25	0.20	0.14	0.70	0.21	0.55	0.92
Mercury	0.19	0.97	0.97	--- (ND)	0.65	1.41	0.34	0.52	0.78
Nickel	6.20	0.56	0.32	1.85	1.37	1.10	0.68	1.65	0.75
Selenium	1.90	1.00	0.63	0.34	0.23	0.58	0.20	0.36	0.66
Silver	1.10	0.24	0.19	0.47	--- (ND)	--- (ND)	0.04	0.08	0.13
Thallium[b]	1.80	--- (ND)	--- (ND)	--- (ND)	--- (ND)	--- (ND)	0.33	--- (ND)	--- (ND)
Zinc	61.8	0.43	0.29	1.88	0.50	1.04	0.38	0.40	0.43

Table 7-32
Comparison of Metal Concentrations in Game with Reference Soil Concentrations[a]
TOAR-FUDS, Tobyhanna, PA

Chemical	Reference Surface Soils Max. Concentration[a] (mg/kg)	Ratio of Site Soil to Reference Soil Concentration							
		T7-SS-4258-001	T7-SS-4258-003_AVG	T8-SS-4258-002	T9-SS-4258-001	T9-SS-4258-003	F4-SS-4258-002_AVG	F5-SS-4257-002	T10-SS-4258-001
Metals									
Antimony	0.99	0.87	0.65	0.99	0.79	0.76	1.41	--- (ND)	0.62
Arsenic	8.80	0.76	0.48	0.89	0.78	0.60	0.65	0.27	0.64
Beryllium[b]	0.72	0.51	0.43	0.57	0.65	0.43	0.99	0.58	0.47
Cadmium	1.10	--- (ND)	--- (ND)	--- (ND)	0.25	--- (ND)	0.27	0.35	--- (ND)
Chromium	9.00	1.11	0.58	1.02	0.91	0.89	0.64	0.22	0.60
Copper	12.6	0.56	0.31	0.33	0.81	0.35	1.00	0.48	0.67
Lead	115	0.34	0.25	0.32	0.40	0.29	0.64	0.41	0.44
Mercury	0.19	0.86	0.42	0.65	0.65	0.50	1.00	0.46	0.54
Nickel	6.20	0.76	0.31	0.40	0.69	0.45	0.65	0.31	0.39
Selenium	1.90	0.49	0.54	0.52	0.79	0.22	0.82	0.35	0.53
Silver	1.10	0.08	--- (ND)	0.07	0.35	--- (ND)	0.11	0.09	0.13
Thallium[b]	1.80	0.61	0.46	--- (ND)	--- (ND)	0.36	--- (ND)	--- (ND)	0.51
Zinc	61.8	0.38	0.19	0.28	0.62	0.34	0.64	0.55	0.29

Table 7-32
Comparison of Metal Concentrations in Game with Reference Soil Concentrations[a]
TOAR-FUDS, Tobyhanna, PA

Chemical	Reference Surface Soils Max. Concentration[a] (mg/kg)	Ratio of Site Soil to Reference Soil Concentration								
		T10-SS-4258-003	T11-SS-4259-001	T11-SS-4259-003	T6-SS-4259-001	T6-SS-4259-003	T7-SS-4258-002	T8-SS-4258-001	T8-SS-4258-003	T9-SS-4258-002
Metals										
Antimony	0.99	0.83	0.64	--- (ND)	1.52	0.99	0.75	1.01	1.92	7.68
Arsenic	8.80	0.41	0.51	0.48	2.51	0.76	0.73	0.69	0.44	0.66
Beryllium[b]	0.72	1.00	0.49	0.43	1.38	0.50	0.49	0.56	0.54	0.51
Cadmium	1.10	0.14	--- (ND)	--- (ND)	0.72	0.22	0.16	--- (ND)	0.23	--- (ND)
Chromium	9.00	0.43	0.52	0.38	1.03	0.34	0.72	1.27	0.40	0.56
Copper	12.6	0.64	0.59	0.35	2.62	0.86	0.80	2.48	0.77	0.61
Lead	115	0.59	0.34	0.20	3.26	1.63	0.76	0.49	1.71	0.58
Mercury	0.19	0.54	0.54	0.28	0.81	0.52	1.03	0.97	0.76	0.81
Nickel	6.20	0.40	0.26	0.16	1.23	0.39	0.68	0.66	0.37	0.31
Selenium	1.90	0.47	0.34	0.21	1.21	0.50	0.84	0.37	0.63	0.53
Silver	1.10	--- (ND)	0.13	--- (ND)	1.09	0.10	0.16	--- (ND)	0.19	0.11
Thallium[b]	1.80	--- (ND)	0.44	--- (ND)	0.78	--- (ND)	--- (ND)	--- (ND)	--- (ND)	--- (ND)
Zinc	61.8	0.29	0.29	0.18	1.73	0.43	0.66	0.33	0.43	0.45

Table 7-32
Comparison of Metal Concentrations in Game with Reference Soil Concentrations[a]
TOAR-FUDS, Tobyhanna, PA

Note: Shading indicates those concentrations that are above expected levels of natural variability (i.e., above 3x the reference background maximum concentration).

[a] Reference background data are summarized in Table 7-46.

[b] Reference values reported for beryllium and thallium are the maximum quantitation limit. Beryllium and thallium were not detected in reference soils.

[c] Value reported in parenthesis is the sample quantitation limit. Not detected in this sample.
ND = Not detected.

Table 7-33
Comparison of Chemical Concentrations in Sediments to Sediment Benchmarks
Sample RA11-SD-4259-00, Game
TOAR-FUDS, Tobyhanna, PA

Chemical[a]	RA11-SD-4259-00 Detected Concentration (mg/kg)	Sediment Benchmarks: CCME PEL[a] (mg/kg DW)	OMEE LEL[b] (mg/kg DW)	EPA Region III BTAG[c] Flora (mg/kg)	EPA Region III BTAG[c] Fauna (mg/kg)	NOAA SQRT Freshwater PEL[d] (mg/kg DW)	Lowest Ecological Benchmark	Ratio of Detected Concentration to Lowest Benchmark
Inorganics								
Antimony	0.63	NBA	NBA	NBA	150	NBA	150	0.0042
Arsenic	6.2	17	6.0	8.2	8.2	17	6.0	1.03
Beryllium	0.97	NBA	NBA	NBA	NBA	NBA	NBA	---
Cadmium	0.65	3.5	0.6	5.1	1.2	3.53	0.6	1.08
Chromium	3.7	90	26	0.005	260	90	0.005	740
Copper	1.6	197	16	NBA	34	197	16	0.1
Lead	23.4	91.3	31	NBA	46.7	91.3	31	0.75
Mercury	ND	0.49	0.2	0.15	0.15	0.49	0.15	---
Nickel	11.5	NBA	16	20.9	20.9	35.9	16	0.72
Selenium	0.64	NBA	NBA	NBA	NBA	1.0	1.0	0.64
Silver	0.52	NBA	NBA	NBA	1	NBA	1.0	0.52
Zinc	116	315	120	NBA	150	315	120	0.97

Note: Shading indicates the detected concentration exceeds the benchmark.
BTAG = Biological Technical Assistance Group.
DW = Dry weight.
LEL = Lowest effect level.
mg/kg = Milligrams per kilogram.
NBA = No benchmark available.
PEL = Probable effect level.
[a] CCME (Canadian Council of Ministers of the Environment), 1998. *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life.*
[b] Persaud, D., R. Jaagumagi, and A. Hayton. 1993. *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* .
[c] Ontario Ministry of Environment and Energy (OMEE). Queens Printer for Ontario.
EPA (U. S. Environmental Protection Agency). 1995. *Region III BTAG Screening Levels - Draft* . September, 1995.
[d] NOAA (National Oceanic and Atmospheric Administration). September 1999. NOAA Screening Quick Reference Tables. Hazmat Report 99-1.

Table 7-34
Comparison of Chemical Concentrations in Sediments to Sediment Benchmarks
Sample T11-SD-4252-001_AVG, Game
TOAR-FUDS, Tobyhanna, PA

Chemical[a]	T11-SD-4252-001_AVG Detected Concentration (mg/kg)	Sediment Benchmarks CCME PEL[a] (mg/kg DW)	OMEE LEL[b] (mg/kg DW)	EPA Region III BTAG[c] Flora (mg/kg)	EPA Region III BTAG[c] Fauna (mg/kg)	NOAA SQRT Freshwater PEL[d] (mg/kg DW)	Lowest Ecological Benchmark	Ratio of Detected Concentration to Lowest Benchmark
Inorganics								
Antimony	ND	NBA	NBA	NBA	150	NBA	150	---
Arsenic	4.6	17	6.0	8.2	8.2	17	6.0	0.77
Beryllium	0.17	NBA	NBA	NBA	NBA	NBA	NBA	---
Cadmium	0.57	3.5	0.6	5.1	1.2	3.53	0.6	0.94
Chromium	11.8	90	26	0.005	260	90	0.005	2,350
Copper	10.5	197	16	NBA	34	197	16	0.66
Lead	15.7	91.3	31	NBA	46.7	91.3	31	0.51
Mercury	0.12	0.49	0.2	0.15	0.15	0.49	0.15	0.8
Nickel	8.5	NBA	16	20.9	20.9	35.9	16	0.53
Selenium	0.44	NBA	NBA	NBA	NBA	1.0	1.0	0.44
Silver	ND	NBA	NBA	NBA	1.0	NBA	1.0	---
Zinc	30.7	315	120	NBA	150	315	120	0.26

Note: Shading indicates the detected concentration exceeds the benchmark.
BTAG = Biological Technical Assistance Group.
DW = Dry weight.
LEL = Lowest effect level.
mg/kg = Milligrams per kilogram.
NBA = No benchmark available.
PEL = Probable effect level.

[a] CCME (Canadian Council of Ministers of the Environment), 1998. *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life.*

[b] Persaud, D., R. Jaagumagi, and A. Hayton. 1993. *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* .

[c] Ontario Ministry of Environment and Energy (OMEE). Queens Printer for Ontario.
EPA (U. S. Environmental Protection Agency). 1995. *Region III BTAG Screening Levels - Draft* . September, 1995.

[d] NOAA (National Oceanic and Atmospheric Administration). September 1999. NOAA Screening Quick Reference Tables. Hazmat Report 99-1.

Table 7-35
Comparison of Chemical Concentrations in Sediments to Sediment Benchmarks
Sample T6-SD-4252-001, Game
TOAR-FUDS, Tobyhanna, PA

Chemical[a]	T6-SD-4252-001 Detected Concentration (mg/kg)	Sediment Benchmarks CCME PEL[a] (mg/kg DW)	OMEE LEL[b] (mg/kg DW)	EPA Region III BTAG[c] Flora (mg/kg)	EPA Region III BTAG[c] Fauna (mg/kg)	NOAA SQRT Freshwater PEL[d] (mg/kg DW)	Lowest Ecological Benchmark	Ratio of Detected Concentration to Lowest Benchmark
Inorganics								
Antimony	ND	NBA	NBA	NBA	150	NBA	150	---
Arsenic	2.8	17	6.00	8.2	8.2	17	6.0	0.47
Beryllium	ND	NBA	NBA	NBA	NBA	NBA	NBA	---
Cadmium	0.99	3.5	0.6	5.1	1.2	3.53	0.6	1.65
Chromium	5.6	90	26	0.005	260	90	0.005	1,120
Copper	20.1	197	16	NBA	34	197	16	1.26
Lead	80.1	91.3	31	NBA	46.7	91.3	31	2.58
Mercury	0.26	0.49	0.2	0.15	0.15	0.49	0.15	1.73
Nickel	6.8	NBA	16	20.9	20.9	35.9	16	0.43
Selenium	1.1	NBA	NBA	NBA	NBA	1.0	1.0	1.1
Silver	ND	NBA	NBA	NBA	1.0	NBA	1.0	---
Zinc	64.1	315	120	NBA	150	315	120	0.53

Note: Shading indicates the detected concentration exceeds the benchmark.
BTAG = Biological Technical Assistance Group.
DW = Dry weight.
LEL = Lowest effect level.
mg/kg = Milligrams per kilogram.
NBA = No benchmark available.
PEL = Probable effect level.
[a] CCME (Canadian Council of Ministers of the Environment), 1998. *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life.*
[b] Persaud, D., R. Jaagumagi, and A. Hayton. 1993. *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* .
[c] Ontario Ministry of Environment and Energy (OMEE). Queens Printer for Ontario.
EPA (U. S. Environmental Protection Agency). 1995. *Region III BTAG Screening Levels - Draft* . September, 1995.
[d] NOAA (National Oceanic and Atmospheric Administration). September 1999. NOAA Screening Quick Reference Tables. Hazmat Report 99-1.

Table 7-36
Comparison of Metal Concentrations with Reference Sediment Concentrations in Game[a]
TOAR-FUDS, Tobyhanna, PA

Chemical	Gameland Site Concentration			Reference Sediments	Ratio of Site Sediment to Reference Sediment Concentration		
	RA11-SD-4259-00 (mg/kg)	T11-SD-4252-001_AVG (mg/kg)	T6-SD-4252-001 (mg/kg)	Max. Concentration[a] (mg/kg)	RA11-SD-4259-00	T11-SD-4252-001_AVG	T6-SD-4252-001
Metals							
Arsenic	6.2	4.6	2.8	28.5	0.22	0.16	0.098
Beryllium	0.97	0.17	ND	ND	---	---	---
Cadmium	0.65	0.57	0.99	4.4	0.15	0.13	0.23
Chromium	3.7	11.8	5.6	ND	---	---	---
Copper	1.6	10.5	20.1	25.8	0.062	0.41	0.78
Lead	23.4	15.7	80.1	780	0.03	0.02	0.1
Mercury	ND	0.12	0.26	ND	---	---	---
Selenium	0.64	0.44	1.1	2.2	0.3	0.2	0.51

Note: Shading indicates those concentrations that are above expected levels of natural variability (i.e., above 3x the reference background maximum concentration).

mg/kg = Milligrams per kilogram.
ND = Not detected.
[a] Reference background data are summarized in the TYAD Ecological Risk Assessment, 1997.

Table 7-37
Comparison of Surface Water Data to Federal and State Water Quality Criteria,
Samples RA11-SW-4259-00, T11-SW-4252-001_AVG and T6-SW-4252-001, Game
TOAR-FUDS, Tobyhanna, PA

Chemical	Detected Concentration (µg/L)			Federal Freshwater AWQC[a]		Pennsylvania WQC[b]		Lowest Ecological Benchmark	Ratio of Detected Concentration to Lowest Benchmark		
	RA11-SW-4259-00	T11-SW-4252-001_AVG	T6-SW-4252-001	CMC (µg/L)	CCC (µg/L)	CMC (µg/L)	CCC (µg/L)		RA11-SW-4259-00	T11-SW-4252-001_AVG	T6-SW-4252-001
Metals											
Arsenic	ND	5.4	ND	340	150	340	150	150	---	0.036	---
Beryllium	1.6	ND	ND	NBA	NBA	NBA	NBA	NBA	---	---	---
Cadmium	ND	1.0	ND	2.13	0.094	4.3	0.80	0.094	---	10.7	---
Chromium	ND	3.25	ND	16	23.8	16	23.8	16	---	0.2	---
Copper	ND	11.5	3.9	13	2.74	13	2.74	2.74	---	4.2	1.42
Lead	ND	31.5	9.7	65	0.54	65	0.54	0.54	---	58.2	17.9
Mercury	ND	0.13	ND	1.4	0.77	1.4	0.77	0.77	---	0.17	---
Nickel	ND	2.6	3.2	470	16.1	470	16.1	16.1	---	0.16	0.199
Silver	0.33	ND	ND	3.4	NBA	3.5	NBA	3.4	0.097	---	---
Zinc	7.0	24.4	11.9	120	36.5	120	36.5	36.5	0.19	0.67	0.326

Note: Shading indicates that the EPC exceeds the benchmarks.
AWQC = Ambient Water Quality Criteria.
CCC = Criteria Continuous Concentration (chronic criterion). Note that the value corresponds to a hardness of 25 mg/L.
CMC = Criteria Maximum Concentration (acute criterion).
µg/L = Micrograms per Liter.
NBA = No Benchmark Available.
WQC = Water Quality Criteria.
[a] EPA (U. S. Environmental Protection Agency). *National Recommended Water Quality Criteria - Correction.* EPA 822-Z-99-001. April 1999.
[b] Title 25, Pennsylvania Code, Section 16.102.

Table 7-38
Comparison of Metal Concentrations with Reference Surface Water Concentrations in Game[a]
TOAR-FUDS, Tobyhanna, PA

Chemical	Gameland Site Concentration RA11-SW-4259-00 (µg/L)	Gameland Site Concentration T11-SW-4252-001_A (µg/L)	Gameland Site Concentration T6-SW-4252-001 (µg/L)	Reference Surface Water Max. Concentration[a] (µg/L)	Ratio of Site Surface Water to Reference Surface Water Concentration RA11-SW-4259-00	Ratio T11-SW-4252-001_AVG	Ratio T6-SW-4252-001
Metals							
Beryllium	1.6	ND	ND	ND	---	---	---
Cadmium	ND	1.0	ND	ND	---	---	---
Copper	ND	11.5	3.9	23	---	0.5	0.17
Lead	ND	31.5	9.7	4.1	---	7.65	2.35

Note: Shading indicates those concentrations that are above expected levels of natural variability (i.e., above 3x the reference background maximum concentration).

µg/L = Micrograms per Liter.
ND = Not detected.
[a] Reference background data are summarized in the TYAD Ecological Risk Assessment, 1997.

Table 7-39
Level 1 SLERA
Comparison of Maximum Detected Soil Concentrations with Ecological Benchmarks in Park
TOAR-FUDS, Tobyhanna, PA

Chemical	Maximum Detected Concentration (mg/kg)	Sample ID	Oak Ridge National Laboratory Benchmarks: Phytotoxicity (mg/kg)[a]	Earthworm Toxicity (mg/kg)[b]	Microorganisms/ Microbial Processes Toxicity (mg/kg)[b]	NOAEL-based Wildlife Benchmarks: Mammals (mg/kg)[c]	Birds (mg/kg)[c]	Region III BTAG Benchmarks (mg/kg)[d]	Ecological SSLs[e]: Plants (mg/kg)	Soil Invertebrates (mg/kg)	Mammals (mg/kg)	Birds (mg/kg)	Lowest Ecological Benchmark (mg/kg)	Ratio of Maximum Detected Conc. to Lowest Benchmark
Explosives														
HMX	0.069	F2A-SS-4257-001	43.0 [k]	43.0 [k]	43.0 [k]	NBA	NBA	NBA	NA	NA	NA	NA	43.0	0.0016
Inorganics														
Antimony	10	T4-SS-4251-001	5.0	NBA	NBA	NBA	NBA	0.48 [g]	NA	78	0.27	NA	0.27	37.0
Arsenic	22.7	T1-SS-4257-003	10	60	100	0.99	10.2	328 [g]	18	NA	46	43	0.99	22.9
Beryllium	1.7	F2-SS-4257-001	10	NBA	NBA	NBA	NBA	0.02 [g]	NA	40	21	NA	0.02	85
Cadmium	1.7	T3-SD-4252-001	4.0	20	20	0.6	0.42	2.5 [g]	32	140	0.36	0.77	0.36	4.72
Chromium	11.6	F2-SS-4257-001	1.0	0.4	10	11	1.61	0.0075 [h]	NA	NA	81 [i]	26 [j]	0.0075	1,547
Copper	167	F2A-SS-4257-002	100	50	100	37	51.5	15 [g]	NA	NA	NA	NA	15	11.1
Lead	611	T4-SS-4251-001	50	500	900	74	4.05	0.01 [h]	120	1700	56	11	0.01	61,100
Mercury	0.47	F2-SS-4257-001	0.3	0.1	30	0.015	0.000051	0.058 [f]	NA	NA	NA	NA	0.000051	9,216
Nickel	13.5	F2-SS-4257-001	30	200	90	24.6	12.1	2.0 [g]	NA	NA	NA	NA	2.0	6.75
Selenium	4.7	F2-SS-4257-001	1.0	70	100	0.021	42	1.8 [f]	NA	NA	NA	NA	0.021	224
Silver	0.85	F2-SS-4257-001	2.0	NBA	50	NBA	NBA	0.0000098 [g]	NA	NA	NA	NA	0.0000098	86,735
Thallium	0.88	T1-SS-4257-003	1.0	NBA	NBA	0.21	NBA	0.001 [g]	NA	NA	NA	NA	0.001	880
Zinc	154	F2-SS-4257-001	50	200	100	160	0.85	10 [g]	NA	NA	NA	NA	0.85	181

Notes:
(1) Shading indicates the maximum detection exceeds the benchmark.
Definitions:
mg/kg = Milligrams per kilogram.
NBA = No benchmark available.
NOAEL = No observed adverse effects level.
[a] ORNL, 1997a. Oak Ridge National Laboratories *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision.*
[b] ORNL, 1997b. Oak Ridge National Laboratories *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision* .
[c] ORNL, 1997c. Oak Ridge National Laboratories *Preliminary Remediation Goals (PRGs) for Ecological Endpoints.* Adjusted LOAEL values in guidance by a factor of 10 to convert to NOAELs.
[d] EPA, 1995. *Region III Biological Technical Assistance Group Screening Levels - Draft.* September, 1995.
[e] EPA, 2005. *Ecological Soil Screening Levels.*
[f] Region III BTAG soil screening level for flora and fauna.
[g] Region III BTAG soil screening level for flora.
[h] Region III BTAG soil screening level for fauna.
[i] Chromium VI value used for mammalian SSL.
[j] Chromium III value used for avian SSL.
[k] Los Alamos National Laboratory; EcoRisk Database, 2004. Note this a general soil guidance level to be protective of soil flora and fauna

Table 7-40
Level 2 SLERA
Comparison of Exposure Point Concentrations with Ecological Benchmarks in Park
TOAR-FUDS, Tobyhanna, PA

Chemical	Exposure Point Concentration (mg/kg)	Oak Ridge National Laboratory Benchmarks: Phytotoxicity (mg/kg)[a]	Oak Ridge National Laboratory Benchmarks: Earthworm Toxicity (mg/kg)[b]	Oak Ridge National Laboratory Benchmarks: Microorganisms/ Microbial Processes Toxicity (mg/kg)[b]	Oak Ridge National Laboratory Benchmarks: NOAEL-based Wildlife Benchmarks: Mammals (mg/kg)[c]	Oak Ridge National Laboratory Benchmarks: NOAEL-based Wildlife Benchmarks: Birds (mg/kg)[c]	Region III BTAG Benchmarks (mg/kg)[d]	Ecological SSLs[e]: Plants (mg/kg)	Ecological SSLs[e]: Soil Invertebrates (mg/kg)	Ecological SSLs[e]: Mammals (mg/kg)	Ecological SSLs[e]: Birds (mg/kg)	Lowest Ecological Benchmark (mg/kg)	Ratio of EPC to Lowest Benchmark
Explosives													
HMX	0.069	NBA	NBA	NBA	NBA	NBA	NBA	NA	NA	NA	NA	NBA	---
Inorganics													
Antimony	4.04	5.0	NBA	NBA	NBA	NBA	0.48 [f]	NA	78	0.27	NA	0.27	14.98
Arsenic	9.14	10	60	100	0.99	10.2	328 [f]	18	NA	46	43	0.99	9.24
Beryllium	0.7	10	NBA	NBA	NBA	NBA	0.02 [f]	NA	40	21	NA	0.02	35.2
Cadmium	0.7	4.0	20	20	0.6	0.42	2.5 [f]	32	140	0.36	0.77	0.36	1.95
Chromium	6.23	1.0	0.4	10	11	1.61	0.0075 [g]	NA	NA	81 [i]	26 [j]	0.0075	831
Copper	58.9	100	50	100	37	51.5	15 [f]	NA	NA	NA	NA	15	3.92
Lead	183	50	500	900	74	4.05	0.01 [g]	120	1700	56	11	0.01	18,290
Mercury	0.19	0.3	0.1	30	0.015	0.000051	0.058 [e]	NA	NA	NA	NA	0.000051	3,630
Nickel	5.07	30	200	90	24.6	12.1	2.0 [f]	NA	NA	NA	NA	2.0	2.54
Selenium	1.52	1.0	70	100	0.021	42	1.8 [e]	NA	NA	NA	NA	0.021	72.5
Silver	0.51	2.0	NBA	50	NBA	NBA	0.0000098 [f]	NA	NA	NA	NA	0.0000098	51,956
Thallium	0.88	1.0	NBA	NBA	0.21	NBA	0.001 [f]	NA	NA	NA	NA	0.001	880
Zinc	77.9	50	200	100	160	0.85	10 [f]	NA	NA	NA	NA	0.85	91.7

Notes:
(1) Shading indicates the EPC exceeds the benchmark.
Definitions:
mg/kg = Milligrams per kilogram.
NBA = No benchmark available.
NOAEL = No observed adverse effects level.

[a] ORNL, 1997a. Oak Ridge National Laboratories. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision.*
[b] ORNL, 1997b. Oak Ridge National Laboratories. *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision.*
[c] ORNL, 1997c. Oak Ridge National Laboratories. *Preliminary Remediation Goals (PRGs) for Ecological Endpoints.* Adjusted LOAEL values in guidance by a factor of 10 to convert to NOAELs.
[d] EPA, 1995. *Region III Biological Technical Assistance Group Screening Levels - Draft.* September, 1995.
[e] EPA, 2005. *Ecological Soil Screening Levels.*
[f] Region III BTAG soil screening level for flora and fauna.
[g] Region III BTAG soil screening level for flora.
[h] Region III BTAG soil screening level for fauna.
[i] Chromium VI value used for mammalian SSL.
[j] Chromium III value used for avian SSL.

Table 7-41
Comparison of Metal Concentrations in Park with Reference Soil Concentrations[a]
TOAR-FUDS, Tobyhanna, PA

Chemical	Reference Surface Soils Max. Concentration[a] (mg/kg)	State Park Site Concentrations F2A-SS-4257-001 (mg/kg)	F2-SS-4257-001 (mg/kg)	F3-SS-4257-001 (mg/kg)	T1-SD-4252-001 (mg/kg)	T3-SD-4252-001 (mg/kg)	T1-SS-4257-002 (mg/kg)	T2-SS-4251-001 (mg/kg)	T2-SS-4251-003 (mg/kg)	T3-SS-4251-001 (mg/kg)	T3-SS-4251-003_AVG (mg/kg)
Metals											
Antimony	0.99	1.20	3.00	0.93	ND (3.70)[c]	ND (6.10)[c]	0.67	ND (1.4)[c]	ND (1.30)[c]	ND (1.40)[c]	0.66
Arsenic	8.80	2.50	10.1	2.00	2.20	4.10	5.40	3.20	5.50	6.20	7.25
Beryllium[b]	0.72	0.68	1.70	0.44	ND (1.50)[c]	ND (2.40)[c]	0.34	ND (0.54)[c]	0.055	ND (0.54)[c]	ND (0.50)[c]
Cadmium	1.10	0.49	1.50	0.57	0.66	1.70	ND (0.83)[c]	0.27	0.42	0.32	0.39
Chromium	9.00	2.50	11.6	2.60	4.90	3.6	4.40	5.4	6.00	4.70	6.45
Copper	12.6	23.8	41.3	10.6	9.00	31.5	14.7	11.1	10.4	11.8	14.2
Lead	115	129	127	75.9	44.6	113	48.0	112	55.2	81.2	88.9
Mercury	0.19	0.20	0.47	0.21	0.10	0.21	0.091	0.057	0.10	0.17	0.09
Nickel	6.20	4.00	13.5	3.20	4.80	7.60	2.30	2.10	6.70	2.40	3.5
Selenium	1.90	1.10	4.70	1.50	1.40	1.70	0.80	0.58	0.76	1.10	0.79
Silver	1.10	0.24	0.85	0.36	ND (1.80)[c]	ND (3.10)[c]	0.094	ND (0.68)[c]	ND (0.63)[c]	0.05	0.056
Thallium[b]	1.80	ND (3.10)[c]	ND (3.60)[c]	ND (2.10)[c]	ND (3.70)[c]	ND (6.10)[c]	ND (1.70)[c]	ND (1.4)[c]	ND (1.30)[c]	ND (1.40)[c]	ND (1.20)[c]
Zinc	61.8	70.9	154	41.7	32.0	104	17.1	13.3	21.7	20.7	18.2

Table 7-41
Comparison of Metal Concentrations in Park with Reference Soil Concentrations[a]
TOAR-FUDS, Tobyhanna, PA

Chemical	Reference Surface Soils Max. Concentration[a] (mg/kg)	State Park Site Concentrations T4-SS-4251-002 (mg/kg)	F2A-SS-4257-002 (mg/kg)	F2-SS-4257-002 (mg/kg)	F3-SS-4257-002 (mg/kg)	T1-SS-4257-001 (mg/kg)	T1-SS-4257-003 (mg/kg)	T2-SS-4251-002 (mg/kg)	T3-SS-4251-002 (mg/kg)	T4-SS-4251-001 (mg/kg)	T4-SS-4251-003 (mg/kg)
Metals											
Antimony	0.99	0.81	0.81	0.57	0.69	0.68	0.77	ND (1.30)[c]	1.80	10.0	5.70
Arsenic	8.80	8.60	6.00	5.40	2.50	3.80	22.7	5.20	6.7	9.50	19.90
Beryllium[b]	0.72	ND (0.40)[c]	0.39	0.35	0.36	0.43	0.41	ND (0.51)[c]	0.07	ND (0.54)[c]	ND (0.56)[c]
Cadmium	1.10	0.27	ND (0.74)[c]	0.68	0.34	0.45	ND (0.81)[c]	0.44	0.47	0.40	0.60
Chromium	9.00	5.00	7.80	3.70	2.20	2.90	3.90	7.40	7.30	7.10	7.20
Copper	12.6	12.7	167	10.7	10.0	12.6	16.8	12.0	14.7	18.8	42.8
Lead	115	247	131	52.2	66.1	65.1	67.1	161	198.0	611	255
Mercury	0.19	0.082	0.15	0.12	0.13	0.12	0.11	0.11	0.10	0.18	0.23
Nickel	6.20	2.80	3.40	3.30	2.30	2.70	2.50	4.70	4.40	2.80	3.60
Selenium	1.90	0.39	0.47	0.94	0.91	1.30	1.40	1.00	0.93	1.30	1.20
Silver	1.10	ND (0.50)[c]	ND (0.74)[c]	0.064	0.21	0.14	0.11	ND (0.64)[c]	ND (0.64)[c]	ND (0.67)[c]	0.05
Thallium[b]	1.80	ND (1.00)[c]	0.70	ND (1.40)[c]	ND (1.60)[c]	ND (1.80)[c]	0.88	ND (1.30)[c]	ND (1.30)[c]	ND (1.30)[c]	ND (1.40)[c]
Zinc	61.8	22.1	72.7	30.9	28.0	28.4	18.6	20.0	25.7	19.0	84.0

Table 7-41
Comparison of Metal Concentrations in Park with Reference Soil Concentrations[a]
TOAR-FUDS, Tobyhanna, PA

Chemical	Reference Surface Soils Max. Concentration[a] (mg/kg)	Ratio of Site Soil to Reference Soil Concentration									
		F2A-SS-4257-001	F2-SS-4257-001	F3-SS-4257-001	T1-SD-4252-001	T3-SD-4252-001	T1-SS-4257-002	T2-SS-4251-001	T2-SS-4251-003	T3-SS-4251-001	T3-SS-4251-003_AVG
Metals											
Antimony	0.99	1.21	3.03	0.94	--- (ND)	--- (ND)	0.68	--- (ND)	--- (ND)	--- (ND)	0.66
Arsenic	8.80	0.28	1.15	0.23	0.25	0.47	0.61	0.36	0.63	0.70	0.82
Beryllium[b]	0.72	0.94	2.36	0.61	--- (ND)	--- (ND)	0.47	--- (ND)	0.08	--- (ND)	--- (ND)
Cadmium	1.10	0.45	1.36	0.52	0.60	1.55	--- (ND)	0.25	0.38	0.29	0.35
Chromium	9.00	0.28	1.29	0.29	0.54	0.40	0.49	0.60	0.67	0.52	0.72
Copper	12.6	1.89	3.28	0.84	0.71	2.50	1.17	0.88	0.83	0.94	1.12
Lead	115	1.12	1.10	0.66	0.39	0.98	0.42	0.97	0.48	0.71	0.77
Mercury	0.19	1.08	2.54	1.14	0.54	1.14	0.49	0.31	0.54	0.92	0.48
Nickel	6.20	0.65	2.18	0.52	0.77	1.23	0.37	0.34	1.08	0.39	0.56
Selenium	1.90	0.58	2.47	0.79	0.74	0.89	0.42	0.31	0.40	0.58	0.42
Silver	1.10	0.22	0.77	0.33	--- (ND)	--- (ND)	0.09	--- (ND)	--- (ND)	0.04	0.05
Thallium[b]	1.80	--- (ND)	--- (ND)	--- (ND)	--- (ND)	--- (ND)	--- (ND)	--- (ND)	--- (ND)	--- (ND)	--- (ND)
Zinc	61.8	1.15	2.49	0.67	0.52	1.68	0.28	0.22	0.35	0.33	0.29

Table 7-41
Comparison of Metal Concentrations in Park with Reference Soil Concentrations[a]
TOAR-FUDS, Tobyhanna, PA

Chemical	Reference Surface Soils Max. Concentration[a] (mg/kg)	Ratio of Site Soil to Reference Soil Concentration									
		T4-SS-4251-002	F2A-SS-4257-002	F2-SS-4257-002	F3-SS-4257-002	T1-SS-4257-001	T1-SS-4257-003	T2-SS-4251-002	T3-SS-4251-002	T4-SS-4251-001	T4-SS-4251-003
Metals											
Antimony	0.99	0.82	0.82	0.58	0.70	0.69	0.78	--- (ND)	1.82	10.10	5.76
Arsenic	8.80	0.98	0.68	0.61	0.28	0.43	2.58	0.59	0.76	1.08	2.26
Beryllium[b]	0.72	--- (ND)	0.54	0.49	0.50	0.60	0.57	--- (ND)	0.10	--- (ND)	--- (ND)
Cadmium	1.10	0.25	--- (ND)	0.62	0.31	0.41	--- (ND)	0.40	0.43	0.36	0.55
Chromium	9.00	0.56	0.87	0.41	0.24	0.32	0.43	0.82	0.81	0.79	0.80
Copper	12.6	1.01	13.25	0.85	0.79	1.00	1.33	0.95	1.17	1.49	3.40
Lead	115	2.15	1.14	0.45	0.57	0.57	0.58	1.40	1.72	5.31	2.22
Mercury	0.19	0.44	0.81	0.65	0.70	0.65	0.59	0.59	0.54	0.97	1.24
Nickel	6.20	0.45	0.55	0.53	0.37	0.44	0.40	0.76	0.71	0.45	0.58
Selenium	1.90	0.21	0.25	0.49	0.48	0.68	0.74	0.53	0.49	0.68	0.63
Silver	1.10	--- (ND)	--- (ND)	0.06	0.19	0.13	0.10	--- (ND)	--- (ND)	--- (ND)	0.05
Thallium[b]	1.80	--- (ND)	0.39	--- (ND)	--- (ND)	--- (ND)	0.5	--- (ND)	--- (ND)	--- (ND)	--- (ND)
Zinc	61.8	0.36	1.18	0.50	0.45	0.46	0.30	0.32	0.42	0.31	1.36

Table 7-41
Comparison of Metal Concentrations in Park with Reference Soil Concentrations[a]
TOAR-FUDS, Tobyhanna, PA

Note: Shading indicates those concentrations that are above expected levels of natural variability (i.e., above 3x the reference background maximum concentration).

[a] Reference background data are summarized in Table 7-46.

[b] Reference values reported for beryllium and thallium are the maximum quantitation limit. Beryllium and thallium were not detected in reference soils.

[c] Value reported in parenthesis is the sample quantitation limit. Not detected in this sample.
ND = Not detected.

Table 7-42
Comparison of Chemical Concentrations in Sediments to Sediment Benchmarks
Samples T1-SD-4252-001 and T3-SD-4252-001, Park
TOAR-FUDS, Tobyhanna, PA

Chemical[a]	Detected Concentration (mg/kg)		Sediment Benchmarks					Lowest Ecological Benchmark	Ratio of Detected Concentration to Lowest Benchmark	
			CCME PEL[a] (mg/kg DW)	OMEE LEL[b] (mg/kg DW)	EPA Region III BTAG[c]		NOAA SQRT Freshwater PEL[d] (mg/kg DW)			
	T1-SD-4252-001	T3-SD-4252-001			Flora (mg/kg)	Fauna (mg/kg)			T1-SD-4252-001	T3-SD-4252-001
Inorganics										
Arsenic	2.2	4.1	17	6.0	8.2	8.2	17	6.0	0.37	0.68
Cadmium	0.66	1.7	3.5	0.6	5.1	1.2	3.53	0.6	1.1	2.83
Chromium	4.9	3.6	90	26	0.005	260	90	0.005	980	720
Copper	9.0	31.5	197	16	NBA	34	197	16	0.56	1.97
Lead	44.6	113	91.3	31	NBA	46.7	91.3	31	1.44	3.65
Mercury	0.1	0.21	0.49	0.2	0.15	0.15	0.49	0.15	0.67	1.4
Nickel	4.8	7.6	NBA	16	20.9	20.9	35.9	16	0.3	0.48
Selenium	1.4	1.7	NBA	NBA	NBA	NBA	1.0	1.0	1.4	1.7
Zinc	32	104	315	120	NBA	150	315	120	0.27	0.87

Note: Shading indicates the detected concentration exceeds the benchmark.
BTAG = Biological Technical Assistance Group.
DW = Dry weight.
LEL = Lowest effect level.
mg/kg = Milligrams per kilogram.
NBA = No benchmark available.
PEL = Probable effect level.
SQRT = Screening Quick Reference Tables.
[a] CCME (Canadian Council of Ministers of the Environment), 1998. *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life.*
[b] Persaud, D., R. Jaagumagi, and A. Hayton. 1993. *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* .
[c] Ontario Ministry of Environment and Energy (OMEE). Queens Printer for Ontario.
EPA (U. S. Environmental Protection Agency). 1995. *Region III BTAG Screening Levels - Draft* . September, 1995.
[d] NOAA (National Oceanic and Atmospheric Administration). September 1999. NOAA Screening Quick Reference Tables. Hazmat Report 99-1.

Table 7-43
Comparison of Metal Concentrations with Reference Sediment Concentrations in Park[a]
TOAR-FUDS, Tobyhanna, PA

Chemical	State Park Site Concentration		Reference Sediments Max. Concentration[a] (mg/kg)	Ratio of Site Sediment to Reference Sediment Concentration	
	T1-SD-4252-001 (mg/kg)	T3-SD-4252-001 (mg/kg)		T1-SD-4252-001	T3-SD-4252-001
Metals					
Cadmium	0.66	1.7	4.4	0.15	0.39
Chromium	4.9	3.6	ND	---	---
Copper	9.0	31.5	25.8	0.35	1.22
Lead	44.6	113	780	0.057	0.14
Mercury	0.1	0.21	ND	---	---
Selenium	1.4	1.7	2.2	0.65	0.79

Note: Shading indicates those concentrations that are above expected levels of natural variability (i.e., above 3x the reference background maximum concentration).

mg/kg = Milligrams per kilogram.
ND = Not detected.
[a] Reference background data are summarized in the TYAD Ecological Risk Assessment, 1997.

Table 7-44
Comparison of Surface Water Data to Federal and State Water Quality Criteria, Samples T1-SW-4252-001 and T3-SW-4252-001, Park
TOAR-FUDS, Tobyhanna, PA

Chemical	Detected Concentration (µg/L)		Federal Freshwater AWQC[a]		Pennsylvania WQC[b]		Lowest Ecological Benchmark	Ratio of Detected Concentration to Lowest Benchmark	
	T1-SW-4252-001	T3-SW-4252-001	CMC (µg/L)	CCC (µg/L)	CMC (µg/L)	CCC (µg/L)		T1-SW-4252-001	T3-SW-4252-001
Metals									
Antimony	ND	ND	NBA	NBA	1100	220	220	---	---
Arsenic	ND	ND	340	150	340	150	150	---	---
Beryllium	ND	ND	NBA	NBA	NBA	NBA	NBA	---	---
Cadmium	ND	ND	2.13	0.094	4.3	0.80	0.094	---	---
Chromium	ND	ND	16	23.8	16	23.8	16	---	---
Copper	1.9	6.4	13	2.74	13	2.74	2.74	0.69	2.34
Lead	4.6	27	65	0.54	65	0.54	0.54	8.5	49.9
Mercury	ND	ND	1.4	0.77	1.4	0.77	0.77	---	---
Nickel	ND	1.4	470	16.1	470	16.1	16.1	---	0.087
Selenium	ND	3.8	NBA	5	NBA	4.6	4.6	---	0.83
Silver	ND	ND	3.4	NBA	3.5	NBA	3.4	---	---
Thallium	ND	ND	NBA	NBA	65	13	13.0	---	---
Zinc	12.1	22.9	120	36.5	120	36.5	36.5	0.33	0.63

Note: Shading indicates that the EPC exceeds the benchmarks.
AWQC = Ambient Water Quality Criteria.
CCC = Criteria Continuous Concentration (chronic criterion). Note that the value corresponds to a hardness of 25 mg/L.
CMC = Criteria Maximum Concentration (acute criterion). T1-SW-4252-001
µg/L = Micrograms per Liter.
NBA = No Benchmark Available.
WQC = Water Quality Criteria.
[a] EPA (U. S. Environmental Protection Agency). *National Recommended Water Quality Criteria - Correction.* EPA 822-Z-99-001. April 1999.
[b] Title 25, Pennsylvania Code, Section 16.102.

Table 7-45
Comparison of Metal Concentrations with Reference Surface Water Concentrations in Park [a]
TOAR-FUDS, Tobyhanna, PA

Chemical	State Park Site Concentration T1-SW-4252-001 (µg/L)	State Park Site Concentration T3-SW-4252-001 (µg/L)	Reference Surface Water Max. Concentration [a] (µg/L)	Ratio of Site Surface Water to Reference Surface Water Concentration T1-SW-4252-001	Ratio of Site Surface Water to Reference Surface Water Concentration T3-SW-4252-001
Metals					
Beryllium	ND	ND	ND	---	---
Lead	4.6	27	4.1	1.12	6.55

Note: Shading indicates those concentrations that are above expected levels of natural variability (i.e., above 3x the reference background maximum concentration).

µg/L = Micrograms per Liter.

ND = Not detected.

[a] Reference background data are summarized in the TYAD Ecological Risk Assessment, 1997.

Table 7-46
Summary of Chemicals Detected in Background Surface Soils in Park and Game
TOAR-FUDS, Tobyhanna, PA

Chemical[a]	Frequency of Detection[a]	Range of Detected Concentrations (mg/kg)	Range of Sample Quantitation Limits[b] (mg/kg)	Arithmetic Mean Concentration[c] (mg/kg)	Standard Deviation[c] (mg/kg)	Data Distribution	95% UCL of the Mean[c] (mg/kg)	Exposure Point Concentration[d] (mg/kg)
Metals								
Antimony	4 / 8	0.41 - 0.99	1.3 - 1.7	0.69	0.18	Normal	0.81	0.81
Arsenic	8 / 8	2.8 - 8.8	NA	5.23	2.26	Normal	6.74	6.74
Beryllium	0 / 8	-	0.51 - 0.72	0.3	0.038	Normal	0.33	0.33
Cadmium	8 / 8	0.31 - 1.1	NA	0.69	0.26	Normal	0.86	0.86
Chromium	8 / 8	3.1 - 9.0	NA	5.24	2.14	Normal	6.67	6.67
Copper	8 / 8	4.9 - 12.6	NA	8.82	2.87	Normal	10.7	10.7
Lead	8 / 8	17.7 - 115	NA	56.4	32.5	Normal	78.2	78.2
Mercury	8 / 8	0.074 - 0.19	NA	0.13	0.039	Normal	0.15	0.15
Nickel	8 / 8	1.3 - 6.2	NA	3.19	1.57	Normal	4.24	4.24
Selenium	8 / 8	0.57 - 1.9	NA	1.22	0.45	Normal	1.52	1.52
Silver	8 / 8	0.3 - 1.1	NA	0.62	0.26	Normal	0.79	0.79
Thallium	0 / 8	-	1.3 - 1.8	0.76	0.09	Normal	0.82	0.82
Zinc	8 / 8	14.1 - 61.8	NA	31.9	18.3	Normal	44.1	44.1

[a] Number of sampling locations at which chemical was detected compared with total number of sampling locations; duplicates at a location were averaged and considered one sample.
[b] Based on nondetected samples.
[c] Nondetects were included at half the sample quantitation limit (EPA, 1989b, 1992).
[d] Based on the lower of the 95% UCL and the maximum detected concentration (EPA, 1989b).
mg/kg = Milligrams per kilogram
UCL = Upper confidence limit

Table 7-47

Detection Limits Compared to Preliminary Ecological Benchmarks For Explosives[a]

TOAR-FUDS, Tobyhanna, PA

	Surface Water			Sediment			Soil			
	Screening Benchmarks		Detection	Screening Benchmarks		Detection	Screening Benchmarks			Detection
	Freshwater (µg/L)	Marine (µg/L)	Limits (µg/L)	Freshwater (µg/kg)	Marine (µg/kg)	Limits (µg/kg)	Earthworms (µg/kg)	Plants (µg/kg)	PRGs[b] (µg/kg)	Limits (µg/kg)
Explosives										
1,3,5-Trinitrobenzene	10 [c]	10 [c]	0.2	240 [c]	240 [c]	0.25	376 [d]	376 [d]	376 [d]	0.25
1,3-Dinitrobenzene	22 [d]	22 [d]	0.2	8.61 [d]	8.61 [d]	0.25	655 [d]	655 [d]	655 [d]	0.25
2,4-Dinitrotoluene	44 [d]	44 [d]	0.2	14.4 [d]	14.4 [d]	0.25	1,280 [d]	1,280 [d]	1,280 [d]	0.25
2,4,6-Trinitrotoluene	90 [c]	90 [c]	0.2	9200 [c]	9200 [c]	0.5	140,000 [c]	30,000 [c]	NA	0.25
2,6-Dinitrotoluene	81 [d]	81 [d]	0.2	39.8 [d]	39.8 [d]	0.5	32.8 [d]	32.8 [d]	32.8 [d]	0.25
dinitrotoluene	20 [c]	20 [c]	0.2	NA	NA	0.25	NA	80,000 [c]	NA	0.25
dinitrotoluene	NA	NA	0.2	NA	NA	0.25	NA	NA	NA	0.25
HMX	330 [c]	330 [c]	0.5	470 [c]	470 [c]	0.3	NA	NA	NA	0.5
Nitrobenzene	220 [d]	220 [d]	0.2	NA	NA	0.25	1,310 [d]	1,310 [d]	1,310 [d]	0.25
RDX (Cyclonite)	190 [c]	190 [c]	0.5	1300 [c]	1300 [c]	0.3	NA	100,000 [c]	NA	0.5
Tetryl	NA	NA	0.2	NA	NA	0.25	NA	NA	NA	0.65
2-Nitrotoluene	NA	NA	0.2	NA	NA	0.65	NA	NA	NA	0.25
3-Nitrotoluene	NA	NA	0.2	NA	NA	0.25	NA	NA	NA	0.25
4-Nitrotoluene	NA	NA	0.2	NA	NA	0.25	NA	NA	NA	0.25

Footnotes

NA = Not available

µg/L = micrograms per liter

ug/kg - micrograms per kilogram

[a] Screening values derived for Raritan Army Arsenal.

[b] Preliminary Remediation Goals (PRGs) used only to screen the bio-accumulative compounds indicated.

[c] Talmage, et.al.,1999. Nitroaromatic Munition Compounds: Environmental Effects and Screening Values. Rev. Environ. Contam. Toxicol. 161:1-156.

[d] U.S. Environmental Protection Agency (USEPA) Region V, RCRA - Ecological Screening Tables, http://www.epa.gov/Region5/rcraca/edql.htm.

Table 7-48
Statistical Comparison of Game and Reference Chemical Concentrations in Surface Soils, TOAR-FUDS, Tobyhanna, PA

Metal	Arithmetic Mean ± Standard Deviation Gameland Soils[a] (mg/kg)	Arithmetic Mean ± Standard Deviation Background[a] (mg/kg)	Statistical Analysis[b] Result
Antimony	1.20 ± 1.39	0.69 ± 0.18	S
Arsenic	6.43 ± 4.72	5.23 ± 2.26	NS
Beryllium[c]	0.48 ± 0.21	0.30 ± 0.038	S
Cadmium	0.39 ± 0.19	0.69 ± 0.26	NS
Chromium	6.26 ± 2.70	5.24 ± 2.14	NS
Copper	10.4 ± 7.49	8.82 ± 2.87	NS
Lead	73.6 ± 77.4	56.4 ± 32.5	NS
Mercury	0.13 ± 0.05	0.13 ± 0.039	NS
Nickel	4.14 ± 2.76	3.19 ± 1.57	NS
Selenium	1.02 ± 0.48	1.22 ± 0.45	NS
Silver	0.28 ± 0.27	0.62 ± 0.26	NS
Thallium[c]	0.89 ± 0.28	0.76 ± 0.090	NS
Zinc	33.2 ± 26.1	31.9 ± 18.3	NS

[a] Nondetects were included at half the sample quantitation limit.

[b] Right-tailed Mann-Whitney U-Test at 95% confidence level.

[c] Beryllium and thallium were not detected in background soils, therefore the detection limits were halved and their statistics are shown above.

NS = Not significantly greater than background ($p > 0.05$)

S = Significantly greater than background ($p < 0.05$)

mg/kg = Milligrams per kilogram

Table 7-49
Statistical Comparison of Park and Reference Chemical Concentrations in Surface Soils, TOAR-FUDS, Tobyhanna, PA

Metal	Arithmetic Mean ± Standard Deviation State Park Soils[a] (mg/kg)	Arithmetic Mean ± Standard Deviation Background[a] (mg/kg)	Statistical Analysis[b] Result
Antimony	1.79 ± 2.31	0.69 ± 0.18	S
Arsenic	6.94 ± 5.45	5.23 ± 2.26	NS
Beryllium[c]	0.45 ± 0.39	0.30 ± 0.038	NS
Cadmium	0.56 ± 0.38	0.69 ± 0.26	NS
Chromium	5.33 ± 2.32	5.24 ± 2.14	NS
Copper	24.8 ± 34.9	8.82 ± 2.87	S
Lead	136 ± 128	56.4 ± 32.5	S
Mercury	0.15 ± 0.090	0.13 ± 0.039	NS
Nickel	4.13 ± 2.64	3.19 ± 1.57	NS
Selenium	1.21 ± 0.89	1.22 ± 0.45	NS
Silver	0.35 ± 0.37	0.62 ± 0.26	NS
Thallium[c]	1.00 ± 0.62	0.76 ± 0.090	NS
Zinc	42.1 ± 36.7	31.9 ± 18.3	NS

[a] Nondetects were included at half the sample quantitation limit.

[b] Right-tailed Mann-Whitney U-Test at 95% confidence level.

[c] Beryllium and thallium were not detected in background soils, therefore the detection limits were halved and their statistics are shown above.

NS = Not significantly greater than background ($p > 0.05$)

S = Significantly greater than background ($p < 0.05$)

mg/kg = Milligrams per kilogram

8. INSTITUTIONAL ANALYSIS

The local agencies and leaders in the affected communities have expressed a very strong desire and willingness to assist with the institutional controls that USACE may propose to implement at the TOAR-FUDS site. The individuals from the agencies interviewed anticipate a formal institutional controls program and USACE guidance and direction on what role their agencies are expected to undertake in the context of an overall public education strategy. Although none of the agencies expressed a desire to lead the effort, most have expressed a willingness to collaborate and support it.

WESTON performed an institutional analysis as part of the RI/FS for the TOAR-FUDS. The results of this analysis are summarized in this section. The institutional analysis was performed in accordance with USACE guidance Data Item Description (DID) OE-100.01. These institutional control strategies rely on the existing powers and authorities of other government agencies to protect the public at large from UXO risks. The complete institutional analysis report is included in this report as Appendix P.

8.1 METHODOLOGY

The methodology used to analyze potential institutional control strategies for reducing the UXO-related risk at the site included the review of government institutions and nongovernment entities that have some form of jurisdiction or ownership of the TOAR-FUDS. The agencies exercising control over the site are the DCNR and the PGC. Interviews with representatives of these agencies, and other local agencies with the ability to assist in public education, were conducted to determine the capabilities and willingness to implement, support and, if necessary, enforce short- and long-term institutional control measures. The information gathered during the discussions with these agencies was included in the development of the recommended institutional controls strategies. Information was collected using the following procedures:

1. Based on knowledge of the area, discussions with USACE and PADEP, and preliminary telephone calls to the various institutions, a list of landowners and potential stakeholders was developed.

2. Initial surveys and telephone interviews were conducted with representatives of the following organizations: DCNR, PGC, PA Bureau of Forestry, Tobyhanna Conservation Association, Monroe and Wayne County Planning Commissions, Monroe Co. Emergency Services, Monroe Co. Control Center, Monroe County District Magistrate, Monroe Co. Commissioners, Wayne Co. Emergency Management Agency, Wayne Co. Conservation District, Appletree Management Group, Coolbaugh Township, and Lehigh Township.

3. Data were collected on forms provided by USACE, and included information regarding organization missions, authorities, and willingness to participate in LUCs. Completed forms are included in Appendix P of this report.

4. Based on information collected during the initial surveys, follow-up surveys and telephone interviews were conducted with representatives of the following organizations: DCNR, PGC, Tobyhanna Conservation Association, Monroe Co. Emergency Services, and Monroe County District Magistrate.

5. Data were collected on forms provided by USACE, and included information regarding willingness to participate in specific LUCs. Completed forms are included in Appendix P of this report.

In general, all organizations interviewed expressed interest/willingness to participate in LUCs. Regarding public education, all organizations would be willing to support and/or participate in various forms of public education, including visual and audio media (videos, radio), printed media (brochures, fact sheets), notification during permitting, web site information, and ad hoc committee participation. Regarding access control, both the DCNR and the PGC would be willing to support additional signage at the site. However, currently, neither the DCNR nor the PGC would support or allow fencing to be erected anywhere in Park or Game.

8.2 SUMMARY OF RECOMMENDATIONS

The recommended institutional control strategies have been selected as a result of discussions with the individuals contacted during preparation of this institutional analysis, WESTON's professional experience with institutional analysis, and overall knowledge of the site and site conditions. The recommendations are considered to be appropriate methods for reducing the risk of UXO hazards to the public. They are intended to be an effective complement to the response action alternatives discussed in the FS. The following recommendations have been selected because they provide the opportunity to influence the largest number of people through the educational process.

8.2.1 Signage and Fencing

Warning signs are currently posted in Park and Game. Additional signage should be posted to provide additional information to the public. Fencing is also an effective option for small portions of the site where the risk of exposure to UXO is high. However, currently, neither the DCNR nor the PGC support fencing being erected anywhere in the Park or Game.

The cost associated with signage and fencing would be relative to the type, quality, and extent of additional signage and/or fencing in small portions of the site. Assuming 10,000 feet of fencing was installed, at $15 per foot, the cost of fencing would be approximately $150,000. Assuming 100 additional signs were installed, at $100 per sign, the cost of additional signage would be approximately $10,000. Annual costs would include maintenance of the fencing and signs.

8.2.2 Notification During Permitting

PGC provides standard application forms and brochures that explain the procedures involved in the hunting/trapping permit processes. Similarly, DCNR requires campers to apply for camping permits. The application for permits should include notification to be provided by DCNR, and possibly, by the PGC. Notification would provide the hunter/camper's with information regarding UXO at the site. This process assures DCNR or PGC that the applicant has been informed that UXO may be located on the site. A one-page information document could be included in these explanations that would describe how to recognize UXO and what procedures should be followed if UXO is found on-site.

The proposed notification/information sheet can be prepared by USACE and provided at no charge to DCNR or PGC, and to hunting license issuing agents (usually sporting goods stores). The cost for the initial documents would be approximately $2,000 to be paid by USACE. They would then be photocopied as needed and included as a part of the existing permit information packets. The proposed notification/information sheets would be distributed only to individuals applying for permits at Park and at Game.

8.2.3 Brochure/Fact Sheet

Brochures and fact sheets describing the history of the TOAR-FUDS and an explanation of UXO hazards should be produced or updated. Text and graphics can be used to describe how to identify UXO, warnings to avoid physical contact in any way, and instructions for dealing with UXO if encountered, including how to report UXO sightings. Fact sheets should be distributed to all property owners near the site. Updated fact sheets should be distributed as additional details on UXO locations, institutional controls, and UXO removal become available. The estimated cost to prepare, print, and distribute a brochure/fact sheet is $13,000.

8.2.4 Newspaper Articles/Interviews

Newspaper articles that discuss the existence of UXO, the potential danger, and how that danger can be minimized through education will serve as a very effective tool for educating the public at no cost to the land owners or USACE. Interviews with USACE, with local residents, and other institutions can be included on an ongoing basis.

8.2.5 Information Packages to Public Officials and Emergency Management Agencies

The proposed brochure/fact sheet, combined with abstracts of additional information on UXO cleanup, mapping, and proposed removal and institutional analysis plans, can be provided to local public officials and emergency management agencies. The production cost for these information packages is already included in the production cost of the fact sheets.

8.2.6 Visual and Audio Media

Two new visual media programs, a 30-minute and a 5- to 7-minute videotape/DVD for classrooms and community groups are recommended. Through classrooms and community groups, these programs could reach a majority of the people in the region. Copies of the videotapes should be provided to local libraries. The estimated cost of preparation of the two visual media programs and making adequate copies available is $26,000. The estimated annual cost to maintain the videos and update them every 3 years averages $2,000 per year.

The use of local radio programming and public television is also recommended to inform and educate the public about the history, current status, and future information concerning the presence of UXO on the former range property. Public television could be offered the 30-minute video for air, and local radio talk shows can be tapped to provide effective venues to have updates and discussions on UXO safety. The existing and future fact sheets should be made available to the radio stations.

8.2.7 Classroom Education

Short presentations and courses in local schools and the community college are also recommended strategies to disseminate information. The 5- to 7- minute visual media video prepared for community groups can be used in the school presentations that are to be facilitated by USACE. No additional expenses should be necessary for the schools. USACE would have expenses of approximately $8,000 for the first year and $3,000 annually for future years.

8.2.8 Internet Website

The DCNR, PGC, and PADEP websites should be updated to include information regarding UXO at the TOAR-FUDS. The existence of the web page should be presented in the fact sheets to be prepared, and in TV or radio coverage discussed above. The total cost to update the websites would be approximately $5,000.

8.2.9 Technical Review Committee

The Technical Review Committee should continue to play a vital role in the review of the TOAR-FUDS RI/FS, to serve as a mechanism for implementing the recommendations of the RI/FS, including this institutional analysis, and to act as the primary proponent for public education of the UXO issues. Meetings will be conducted at an annual cost of approximately $2,000.

8.2.10 Reverse 911 System

The use of a reverse 911 system should be investigated with the county emergency management agency to address potential evacuations. Reverse 911 is an interactive community notification system that can be used to quickly contact citizens in every specific geographic area to communicate urgent information regarding UXO issues (e.g., a fire in the vicinity of an area of known or suspected UXO contamination). This can be a joint police, fire, and EMS function with various federal, state, and local dollars to purchase the system. The shared cost of a basic eight-line system is approximately $25,000.

8.2.11 Other

Other institutional controls were evaluated; however, they were not determined to be as effective in informing a substantial part of the population. Therefore, those institutional controls are not recommended, as discussed in detail in Appendix P.

9. SUMMARY AND CONCLUSIONS

This section provides a summary of the results of the remedial investigation conducted at the TOAR-FUDS, including the nature and extent of MEC and MC, and the risk associated with each. A discussion of uncertainty related to the characterization of the TOAR-FUDS is also included.

9.1 SUMMARY OF REMEDIAL INVESTIGATION RESULTS

9.1.1 Munitions and Explosives of Concern

As described in Section 2, the TOAR-FUDS is located in Monroe County, with a small portion of the northern portion of the site within Wayne County, in northeastern Pennsylvania. The TOAR-FUDS consists of two adjacent land areas owned by the Commonwealth of Pennsylvania and divided by I-380. The northeastern portion is managed by DCNR and is comprised of portions of Park. The southwestern portion is managed by the PGC and is comprised of portions of Game.

As discussed in Section 3, a combination of IAR and DGM investigative methods were performed at the TOAR-FUDS to characterize the nature and extent of MEC at the site, validate and refine the CSM, and support risk-based selection of MEC response alternatives. IAR was used to search for and collect data or evidence of military or MEC activities in an area, and was also used to assist in placing DGM transects and grids. DGM grids were used to quantify types and densities of potential MEC contamination, and DGM transects were used to determine the horizontal extents of contamination

As discussed in Section 4, using the data from all sources, the site can be characterized with a relatively high degree of certainty for MEC contamination. The sources of data, or lines of evidence, used to characterize the site include the following:

1. Historical information
    a. ASR

   b. EPA EPIC Study
   c. Historical maps
2. UXO recovered during all previous work at the TOAR-FUDS and MD recovered during WESTON activities at the TOAR-FUDS
   a. 1998 HFA TCRA – Park
   b. 1998 HFA Construction Support – TYAD
   c. 2004 WESTON Construction Support – TYAD
   d. 2004 WESTON TCRA – Game
   e. 2004 WESTON site visits
   f. 2004 CENAB site visits
   g. 2004 WESTON RI
3. Artillery range layouts
   a. Historical layouts (USACE provided)
   b. Current range layout standards
4. Visual evidence.
   a. Targets
   b. Powder bunkers
   c. Impact craters
5. Local knowledge.
   a. Local historian
   b. TYAD Environmental Coordinator
   c. Park and Game personnel
   d. Stakeholders
6. MC sampling results.

The ASR summarizes the site, historical ordnance presence, site eligibility for the FUDS program, and results of a visual site inspection, and provides an evaluation of ordnance and other site hazards. In the preparation of the ASR, historical records were searched and site interviews conducted with numerous personnel. The results of the effort are contained in detail in the numerous appendices of the report, and provided the baseline of information used in the development of the initial CSM and plans.

EPA's National Exposure Research Laboratory, through its EPIC Center, analyzes historical records such as aerial imagery, historic and thematic maps, and other cartographic data for environmental site analyses and civil and criminal actions. Aerial imagery of the TOAR-FUDS was collected from between 1939 and 1999. The EPIC study further supported the ASR findings.

Historical maps not included in the ASR were located in 2003 during the initial project site visit. Several maps were found, but the most important map was a small scale 1920s era hand drawn range map, which was located in the Park Ranger's office. This map, shown in Figure 2-4, was used to validate other maps and known information on FPs and TAs at the TOAR-FUDS. This map detailed the placement of the ranges (firing points, targets and range fans) and was crucial in supporting the characterization of the site. Other maps were also located and used but were not as beneficial as the 1918 map.

In total, approximately 578 acres of the site have been physically investigated or subjected to some form of removal action. In Park, total acres investigated were as follows:

- 1998 HFA TCRA – 187.5 acres were investigated in selected areas.
- 1998 HFA TCRA – 18 acres along were investigated hiking trails.
- 2004 WESTON RI – 31.71 acres were investigated using DGM.
- 2004 WESTON RI – 183.56 acres were investigated using IAR.
- Site visits – numerous acres have been visually inspected during site visits.

In Game, total acres investigated were as follows:

- 2004 WESTON TCRA – 27 acres were investigated along roadways and trails.
- 2004 WESTON RI – 41.60 acres were investigated using DGM.

- 2004 WESTON RI – 86.73 acres were investigated using IAR.
- Site visits – numerous acres have been visually inspected during site visits.

During the 2004 WESTON RI, a total of 6,422 anomalies were selected for reacquisition and subsequent intrusive investigation. As summarized in Table 4-2, of those 6,422 anomalies investigated, 78 UXO were recovered at the site: 40 UXO in Park (two of which were recovered from within the Lake Watawga Area), and 38 UXO in Game. Also, 3,367 MD were recovered, 2,584 non-MEC were recovered, and 392 false positives were identified. MD recovered included frag, base plates, empty projectiles, flash tubes, expended fuzes, and noses. At the TOAR-FUDS, empty projectiles were the principal MD that might have been indicative of a UXO presence. No DMM was recovered and no disposal pits were found at the site.

In addition to those items recovered during the 2004 WESTON RI, UXO recovered during previous activities include the following:

- 278 UXO recovered in Park (at the campground and along trails) during 1998 HFA TCRA.
- 228 UXO recovered on-post at TYAD (at the radar facility) during 1998 HFA construction support activities.
- 7 UXO recovered on-post at TYAD (adjacent to the radar facility) during 2004 WESTON construction support activities.
- 1 UXO recovered in Game (near 7-Mile Road and Jeep Trail) during 2004 WESTON TCRA.
- 3 UXO recovered in Park (near trails) during 2004 WESTON site visit.
- 2 UXO recovered in Park (near the northern FUDS boundary within the Lake Watawga Area) during 2004 CENAB site visit.

The largest artillery used at the TOAR-FUDS was 155-mm. As shown in Figures 4-1 and 4-2, all UXO recovered during all investigations were recovered in TAs and RFs where UXO contamination was expected based on historical artillery range use. No DMM was recovered and no disposal pits were found. Therefore, no MEC was recovered that could be associated with former activities at FPs. Also, no UXO was recovered in Other Areas, which was expected because Other Areas were outside the area of expected or anticipated contamination.

Four UXO were recovered within the BZ in Park. Two of these items were recovered during the 2004 CENAB site visit, and the other two items were recovered during the 2004 WESTON RI. The UXO were found inside the northern FUDS boundary, southeast of Lake Watawga, as shown in Figure 4-1. Upon finding the UXO, the minimum separation distance (MSD) for investigative work increased from 200 ft to 2,577 ft, based on the MGFD, the 155-mm M107. Residential housing is located within 500 ft of the UXO. Therefore, due to safety concerns regarding the residential housing, CENAB halted intrusive investigation. Due to the proximity of UXO and MD to residential housing, and due to fire suppression issues in areas of known or potential UXO contamination, CENAB deemed the area to be in need of a remedial action or a removal action, and halted intrusive characterization efforts. The Lake Watawga Area is shown in Figure 4-15. No UXO are known to have been found outside the FUDS boundary, and the FUDS boundary itself is presumed to be reasonably accurate. Therefore, CENAB established a MSD of 200 ft for investigative work outside the FUDS boundary. Additional investigation north of the FUDS boundary located no additional UXO.

Visual evidence was collected throughout the RI to locate MEC and to support characterization of the TOAR-FUDS for MEC. Visual evidence used to support site characterization for MEC consisted primarily of the presence or absence of targets (i.e., wagons) and/or cratering in IAs and in BZs.

Field notes recorded by USRADS crew members while surveying DGM grids for investigation during the RI indicated that craters were found throughout grids surveyed in Targets #7, #8, #9, #10, and #11 in Game, and Targets #2 and #3 in Park, which supports the characterization of those areas as IAs. Also, no visual evidence of mass cratering was noted during investigation in BZs and Other Areas. Remnants of targets (the remaining metal portion of the wood/metal wagons used as targets) were also observed in each target area by field crews and at Target #4 during the initial RI/FS project site visit by WESTON in 2003. Powder bunkers (intact or remains) were also noted in the vicinity of the FPs described in the initial CSM and in historical data. The presence of these bunkers allows for more precise placement of the FPs, which in turn allows for accurate revision of the CSM: using a precise FP and target location, the dividing line for buffer and other areas is more well-defined.

Extensive local knowledge was supplied by area residents, the local historian, PGC and DCNR employees, and the TYAD Environmental Coordinator. Of particular help was one DCNR employee, who has lived in the area for years and has hiked nearly the entire site (both Park and Game). He was instrumental in providing information on where use occurred, what might be found and was able to either lead field crews to the exact locations or highlight the area on a map. In all instances his data was accurate. This information was used to focus investigations, eliminate unnecessary investigations (e.g., across the southern region of Game), and refine the CSM.

The local historian and the TYAD Environmental Coordinator also provided historical information on potential areas of concern and the items that were used during the periods of time the site was active. The TYAD Environmental Coordinator also supported the project RI and site characterization efforts with additional historical photographs and information from the TYAD archives.

The last source of local knowledge came from local, long term residents. At all public meetings (numerous meetings were held during the preparation for and the conduct of the RI), maps were available to residents and they were queried for any information they may have gained about targets, munitions use, etc during their time in the area. Much of this information was provided by hunters who spend many days in the Game preparing for or participating in hunting season. This information was recorded on the working maps and then used to continue refining the site characterization results.

Environmental samples were collected at biased-high locations (ordnance features such as detonation craters and within impact areas) to evaluate the presence of MC contamination. Metals (particularly lead) were present in soils, sediments, and surface water within ordnance features and within IAs at concentrations that exceed background levels.

Based on the field data collected during the RI and during previous investigations at the TOAR-FUDS, and all other lines of evidence, revisions to the CSM were deemed necessary to account for high densities of UXO and MD recovered in some areas, and to account for the extensive cratering observed in some areas. To revise the CSM, TAs were first conservatively redrawn to include high densities of UXO, MD indicative of a potential UXO presence (empty projectiles), and heavily cratered areas. The TA boundaries were drawn to include the expected distribution of all UXO at a target, per U.S. Army Field Manual (FM) 6-40, Marine Corps Warfighting Publication (MCWP) No. 3-16.4, "Tactics, Techniques, and Procedures for Field Artillery Manual Cannon Gunnery" (U.S. Army, 1999). The TAs were shaped to closely resemble the generic TAs shown in Figure 4-17, and were aligned in the general direction of the applicable FPs. Then, using the artillery range layout shown in Figures 4-17, IAs were delineated at distances of 240 meters, 160 meters, and 32 meters from the front, rear, and side borders of the TAs, respectively. Finally, using the artillery range layout shown in Figure 4-18, BZs were delineated at 1,000 yards from the boundary of the IAs. It should be noted that due to the use of shrapnel rounds (which are often times used for final protective fires or last line of defense) BZs cannot include safe overhead areas between FPs and TAs. Based on the revised CSM, shown in Figures 4-15 and 4-16, all UXO recovered to date at the TOAR-FUDS are within expected areas of contamination (IAs and BZs).

UXO Estimator Module 2 was also used to analyze the data collected in the field for the revised CSM. The results calculated by UXO Estimator Module 2 for both DGM and IAR data for the revised CSM at the TOAR-FUDS are presented in Table 4-27. DGM data was principally considered when interpreting the output from Module 2. The results for DGM data can be summarized as follows:

- Other Areas – Confidence levels (95% for target density of 0.5 UXO/acre) are met for the target density using DGM data in both Park and Game. There is a 99.00% and 99.89% certainty that less than 0.5 UXO/acre is present in Other Areas in the Park and Game, respectively, and no additional investigation is required to characterize the areas. This output from Module 2 agrees with the information derived from the generic artillery range layouts, the ASR, and the data from previous investigations.
- Buffer Zones – Confidence levels (95% for target density of 0.5 UXO/acre) are met for the target density using DGM data in Park, but are not met in Game. There is a 98.85% certainty that less than 0.5 UXO/acre is present in the BZ in Park. There is an 83.01% certainty that less than 0.5 UXO/acre is present in the BZ in Game, which means that additional investigation may be warranted to confirm that UXO densities are less than 0.5 UXO/acre. However, other factors should be considered in order to adequately characterize the BZ in Game, including the following:
  - Visual evidence – No visual evidence of mass cratering was noted during investigation in BZs, which indicates the areas are not TAs or IAs.

- Generic artillery range layouts – As discussed in subsection 4.3.1, the artillery range layouts shown in Figures 4-17 and 4-18 were developed by USACE based on historic artillery range data. These layouts were used to develop the BZs in the revised CSM for the TOAR-FUDS.

- Actual UXO density and average UXO density expected – In Game, two UXO were found in the BZ using DGM, therefore the actual density is 0.208, as shown in Table 4-26. The average density expected as calculated by UXO Estimator Module 2 is 0.311. Both densities are less than the target density of 0.5. Therefore, while the confidence levels are not met using DGM according to Module 2, the average densities expected fall within the target density.

- Wet areas – Approximately 25% of the TOAR-FUDS is covered by wet areas (lakes, ponds, streams, wetlands, etc.). Approximately 1519 acres in the buffer zone in Game are considered wet areas. As discussed in Section 3, investigation for UXO is not practicable in wet areas. Therefore, the extent of wet areas in the BZs prevented the collection of additional investigation data in some areas.

- UXO recovered in buffer zones during previous investigations – One UXO was recovered in the BZ in Game during the 2004 WESTON TCRA. No other UXO have been recovered in the BZ in Game during previous investigations. In general, UXO recovered in BZs at the TOAR-FUDS have been recovered in the vicinity of IAs. This is indicative of the fact that UXO density in BZs is expected to vary based on proximity to IAs. Also, the UXO recovered at the intersection of 7-Mile Road and Jeep Trail in Game during the WESTON TCRA and the UXO recovered along the Blue Trail in Park during the HFA TCRA were likely picked up and moved by scrap hunters and/or souvenir collectors from the place they landed (the impact/target area) to the location where they were recovered (with the rotating band missing).

- MD recovered in buffer zones during the RI – 167 MD were recovered in the Park BZ during the RI, and 315 MD were recovered in the Game BZ during the RI. The locations and densities of MD recovered, and MD indicative of a UXO presence (empty projectiles), were considered in the development of the TAs and the IAs in both Park and Game.

▪ Impact Areas – Confidence levels (95% for target density of 0.5 UXO/acre) are not met for the target density using DGM data in both Park and Game. That is, there is a 0% certainty that less than 0.5 UXO/acre is present in IAs in Park and Game. Also, average UXO densities expected are well above the target density of 0.5. This output from Module 2 agrees with the information derived from the generic artillery range layouts, the ASR, and the data from previous investigations.

▪ Lake Watawga Area – A minimal number of acres were investigated intrusively using DGM methods in the Lake Watawga area due to safety concerns. Therefore, UXO Estimator Module 2 was not used to analyze UXO density in the Lake Watawga area. Therefore, other factors such as UXO recovered in the Lake Watawga area during previous investigations and public safety, as discussed in Subsection 4.3.2, are of greater consequence when characterizing the Lake Watawga area and evaluating risk related to UXO.

The uncertainty associated with the use of UXO Estimator is discussed in subsection 9.2.1.

As discussed in Section 7.1, the results of the RI were used to evaluate risk associated with UXO at the TOAR-FUDS. A qualitative risk evaluation was conducted using the Ordnance and Explosives Risk Impact Assessment (OERIA) Interim Guidance document (USACE, 2001) to assess explosive safety risks to the public at the TOAR site. The potential risks posed by UXO were characterized qualitatively by evaluating the following three primary risk factors and associated secondary risk factors:

1. Presence of a UXO source.
    a. Type.
    b. Sensitivity.
    c. Density.
    d. Depth distribution.
2. Site Characteristics – Affect the accessibility or pathway between the source and human receptor.
    a. Site accessibility.
    b. Site stability.
3. Human Factors – Defines the number of receptors and type of activities that may result in direct contact between a receptor and UXO source.
    a. Site activity.
    b. Population.

Using those factors, risk associated with UXO at the TOAR-FUDS was evaluated for FPs, IAs, BZs, Other Areas, and the Lake Watawga area. The results of the risk evaluation are summarized in Table 7-7, and are as follows:

- Firing Points – Risk associated with UXO is low.

- Impact Areas – Risk associated with UXO is high.
- Buffer Zones – Risk associated with UXO is low-moderate, depending on proximity to IAs.
- Lake Watawga Area – Risk associated with UXO is high.
- Other Areas – Risk associated with UXO is low.

Based on the various lines of evidence, the revised CSM, and the results of the risk evaluation, nine (9) Areas of Concern (AOCs) have been identified at the TOAR-FUDS. The AOCs are summarized in Table 9-1 and shown in Figure 9-1. As summarized in Table 9-1, five (5) AOCs have high risk associated with UXO, two (2) AOCs have low-moderate risk associated with UXO, and two (2) AOCs have low risk associated with UXO. The lines of evidence used to characterize the AOCs are summarized in Table 9-2.

9.1.2 Munitions Constituents

The intent of the environmental sampling program for this project was to evaluate the presence of MC contamination resulting from the use of munitions at the TOAR-FUDS, not to provide full site characterization for MC. Therefore, soil, sediment, and surface water samples were collected at biased-high locations (ordnance features, such as detonation craters and disposal pits, and analyzed for metals and explosives) with the highest potential for MC contamination.

MC sampling results are summarized in Section 4.2, and the potential impact of MC on human health and ecological receptors is assessed in Section 7.2 as part of a risk assessment. The results of environmental sampling were analyzed three ways in the screening level risk assessment: 1) results for Park only, 2) results for Game only, and 3) results for Park and Game combined. The results were analyzed three ways to ensure that elevated concentrations in either Park or Game would not be lost in a combined, site-wide assessment.

Only one explosive was detected above method detection limits. HMX was detected in one soil sample collected from FP #2A at a concentration of 0.069 mg/kg, which is above the method detection limit (0.048 mg/kg), but below the reporting limit (0.50 mg/kg). The lack of explosives detected above method detection limits in any other samples helps eliminate

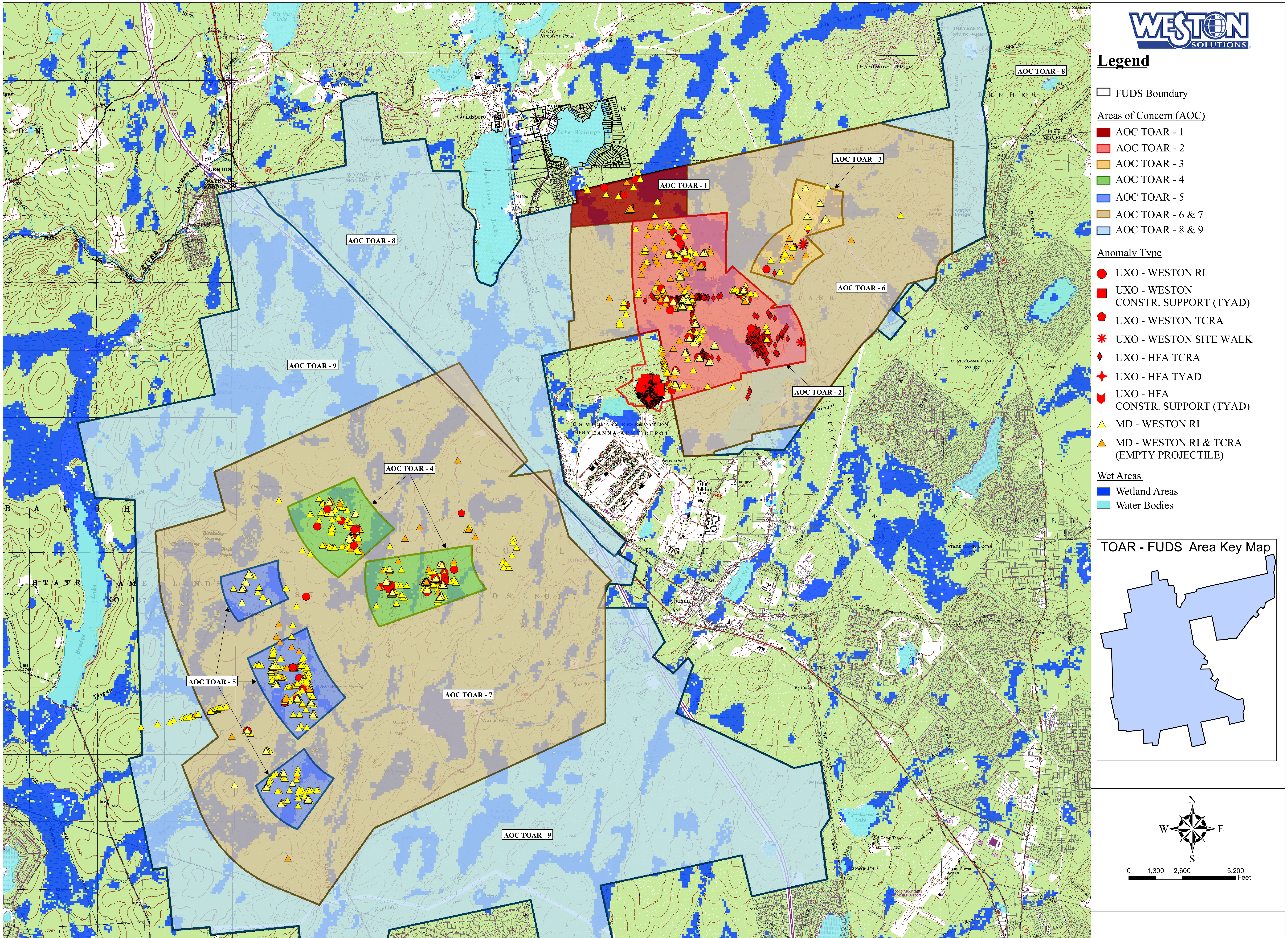

Figure 9-1
Areas of Concern
at TOAR - FUDS

Table 9-1
Areas of Concern at the TOAR-FUDS

Area of Concern	Location	Total AOC Acreage	Wet AOC Acreage[1]	Total Accessible Acreage[2]	Acres Investigated During 2004 RI		Approx. Acres Investigated During All Previous Investigations	Total Approx. Acres Investigated in AOC[3]	UXO Recovered in AOC During 2004 RI	UXO Recovered in AOC During All Previous Investigations	Total UXO Recovered in AOC[4]	Physical Features and Land Uses	UXO Risk
					DGM	IAR							
AOC TOAR-1	Lake Watawga Area	265	99	166	0.42	54.05	1	55	2	2	4	Adjacent residential housing	High
AOC TOAR-2	Impact Area Park	1103	266	837	8.59	25.64	201	235	37	270	307	Camping, hiking, fishing, mountain biking, snowmobiling	High
AOC TOAR-3	Impact Area Park	254	98	156	4.44	2.23	2	9	1	6	7	Camping, hiking, fishing, mountain biking, snowmobiling	High
AOC TOAR-4	Impact Area Game	656	142	514	6.42	9.21	0	16	28	0	28	Hunting, fishing, hiking, mountain biking, snowmobiling	High
AOC TOAR-5	Impact Area Game	625	126	499	10.45	6.64	0	17	7	0	7	Hunting, fishing, hiking, mountain biking, snowmobiling	High
AOC TOAR-6	Buffer Zone Park	2908	612	2296	8.91	54.29	3	66	0	5	5	Camping, fishing, hiking, mountain biking, snowmobiling	Low-Moderate
AOC TOAR-7	Buffer Zone Game	7304	1577	5727	11.21	36.25	20	67	3	1	4	Hunting, fishing, hiking, fishing, mountain biking, snowmobiling	Low-Moderate
AOC TOAR-8	Other Areas Park	3790	525	3265	9.20	49.37	0	59	0	0	0	Adjacent residential housing, hiking, fishing, mountain biking, snowmobiling	Low
AOC TOAR-9	Other Areas Game	4195	1847	2348	13.66	34.40	7	55	0	0	0	Adjacent residential housing, hunting, fishing, hiking, mountain biking, snowmobiling	Low

[1]Wet acreage based on GIS coverage of TOAR-FUDS from 2000, and includes lakes, ponds, streams, wetlands, etc.

[2]Total accessible acreage = Total acreage – Total wet acreage.

[3]Total approximate acres investigated = Acres investigated during 2004 RI + Approximate acres investigated during all previous investigations.

[4]Total UXO recovered = UXO recovered during 2004 RI + UXO recovered during all previous investigations.

Table 9-2
Lines of Evidence for Areas of Concern at the TOAR-FUDS[1]

Area of Concern	Location	Historical Information	EPA Photo Analysis Report	UXO Presence	Range Layout/ Characteristics	MD Presence	Visual Evidence	Local Populace/ Workers Knowledge	IAR or DGM Data?	MC Presence
AOC TOAR-1	Lake Watawga Area	ASR	N	4	Previously part of Range Fans	Y	CENAB Site Visit	Not identified by local populace or workers	Y	N
AOC TOAR-2	Impact Area Park	ASR 1918 Map 1932 Map	Y	307	Historic and Current	Y	Weston Site Visit Target Remnants Impact Craters	Local Historian Park & Game Workers Stakeholders	Y	N
AOC TOAR-3	Impact Area Park	ASR 1918 Map 1932 Map	Y	7	Historic and Current	Y	Target Remnants Impact Craters	Local Historian Park & Game Workers Stakeholders	Y	N
AOC TOAR-4	Impact Area Game	ASR 1918 Map 1932 Map	Y	28	Historic and Current	Y	Target Remnants Impact Craters	Local Historian Park & Game Workers Stakeholders	Y	N
AOC TOAR-5	Impact Area Game	ASR 1918 Map 1932 Map	Y	7	Historic and Current	Y	Target Remnants Impact Craters	Local Historian Park & Game Workers Stakeholders	Y	N
AOC TOAR-6	Buffer Zone Park	ASR 1918 Map 1932 Map	Y	5	Historic and Current	Y	Powder Bunkers No mass cratering	Local Historian Park & Game Workers Stakeholders	Y	N
AOC TOAR-7	Buffer Zone Game	ASR 1918 Map 1932 Map	Y	4	Historic and Current	Y	Powder Bunkers No mass cratering	Local Historian Park & Game Workers Stakeholders	Y	N
AOC TOAR-8	Other Areas Park	Remaining Areas Outside Range Fans	N	0	Remaining Areas Outside Range Fans	Y	No Target Remnants No Impact Craters No Powder Bunkers	Local Historian Park & Game Workers Stakeholders	Y	N
AOC TOAR-9	Other Areas Game	Remaining Areas Outside Range Fans	N	0	Remaining Areas Outside Range Fans	Y	No Target Remnants No Impact Craters No Powder Bunkers	Local Historian Park & Game Workers Stakeholders	Y	N

[1]Lines of evidence used to characterize site are described in subsection 4.3.

Y = Yes.

N = No.

explosives as potential contaminants of concern. Several metals were detected in soil, sediment and surface water samples at concentrations exceeding background levels:

- Lead was detected in all soil samples, all sediment samples, and five of six surface water samples. Maximum concentrations of lead in soil (611 mg/kg) and surface water (31.5 mg/kg) exceed background or reference values.
  - Human Health – Although lead was found to be statistically significant different from background soil levels in Park only samples, lead only exceeded the lowest screening benchmark in 1 of the 45 analyzed samples with a concentration of 611 mg/kg. The lowest screening benchmark was the EPA OSWER residential screening level (400 mg/kg). The arithmetic mean for lead for the Park data (with the highest mean of all three areas) was 136 mg/kg which is well below the EPA OSWER residential value. Therefore, the impact of site lead levels is small relative to background and not likely to pose a human health threat at the Tobyhanna site.
  - Ecological – Lead exceeded background levels and lowest ecological benchmarks in only 2 of 45 soil samples (1 in Park, 1 in Game) and 5 of 6 surface water samples. Although the surface water concentrations of lead in 5 of 6 sampling locations exceeded AWQC, several conservative assumptions were made in this analysis, as discussed in subsection 7.2.2.6.2. Based on the sampling results and the uncertainty inherent in ecological benchmarks, lead detected at the site is not expected to pose an ecologically significant risk to terrestrial organisms at the site.
- Copper was also detected in all soil samples, all sediment samples, and five of six surface water samples. Maximum concentrations of copper in soil (167 mg/kg) and sediment (31.5 mg/kg) exceed background or reference values.
  - Human Health – Although copper exceeded background or reference values, copper did not exceed lowest residential screening benchmarks for human health. Therefore, copper is not a chemical of potential concern at the Tobyhanna site.
  - Ecological – Copper exceeded background levels and lowest ecological benchmarks in only 3 of 45 soil samples (all in Park). Based on the sampling results and the uncertainty inherent in ecological benchmarks, copper detected at the site is not expected to pose an ecologically significant risk to organisms at the site.
- Antimony was detected in 38 of 44 soil samples, and the maximum concentration of antimony in surface soils (10 mg/kg) exceeds background or reference values.
  - Human Health – Although antimony was found to be statistically significant different from background soil levels in all sample combinations (combined Park and Game samples, Park only samples, and Game only samples), antimony only

exceeded the lowest screening benchmark in 6 of the 45 analyzed samples. The lowest screening benchmark was the residential soil RBC (3.13 mg/kg) which was adjusted for preliminary screening purposes to a THQ of 0.1. No antimony samples would exceed the residential RBC at a THQ of 1.0 (31.3 mg/kg). Furthermore, no antimony samples exceed the industrial RBC (40.9 mg/kg), PA DEP MSCs for direct contact (1100 mg/kg) or soil to groundwater protection (27 mg/kg). Therefore, the impact of site antimony levels is small relative to background and not likely to pose a human health threat at the Tobyhanna site.

- Ecological – Antimony exceeded background levels and lowest ecological benchmarks in only 4 of 45 soil samples (3 in Park, 1 in Game). Based on the sampling results and the uncertainty inherent in ecological benchmarks, antimony detected at the site is not expected to pose an ecologically significant risk to organisms at the site.

Potential pathways for these metals include: airborne dust particles; waterborne particles in storm or river runoff; dissolution in storm runoff or other surface water movement; and dissolution in groundwater. Airborne dust is not considered a problem. Retained strongly in soil, very little lead, copper and antimony is expected to be transported into surface water or groundwater in the dissolved state leaving the only pathway of possible concern is waterborne metal-rich sediments in storm and river runoff.

The transport and mobility of both lead and copper increases with low soil or water pH, high amounts of annual precipitation, and the absence of organic compounds in the soil. Similarly, the strength of antimony's adsorption to soil and sediments appears to be dependent upon a variety of factors such as pH, organic matter content, as well as the oxidation state of the particular salt. In water, it usually adheres to sediments. Soil type, organic matter content, topography and the extent of vegetative cover also play a significant role in the transport and mobility of these metals. Soils within the TOAR-FUDS are developed in loamy, glacial deposits derived from shales, siltstones and sandstones with pH values ranging from 4.5 to 6 and a thick, slowly permeable fragipan subsoils. Such soils tend to inhibit vertical migration of the metals while increasing residence time and the probability for electrostatic bonding and adsorption of the metals to soils particles. Field personnel describe soils encountered during the RI as having a thick root/organic layer that also enhances bonding and adsorption to soils. Lastly, the highly vegetated swamp and surrounding forested areas further decrease the potential for movement of sediment to local streams and ponds.

Based on the results of the risk assessments conducted for MC, as well as the fate and transport analysis, additional evaluation or sampling for MC is not warranted.

9.2 DISCUSSION OF UNCERTAINTY

According to EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1998), the goal for cost estimates in a FS is a +50%/-30% accuracy level. Sufficient site characterization data should be collected during the RI phase to allow costing of remedial alternatives during the FS using the stated goal, and data needs should specify a level of allowable uncertainty to meet the goal.

The guidance goes on to state that "in the development of data requirements, time and resource constraints must be balanced with the desired confidence level of the data" and "absolute accuracy of cost estimates during screening (of alternatives) is not essential. The focus should be to make comparative estimates for alternatives with relative accuracy so that cost decisions among alternatives will be sustained as the accuracy of cost estimates improves beyond the screening process."

This section describes the elements of the RI program that impacted relative uncertainties and influenced how time, resource, and site constraints were balanced with the desired level of confidence in site characterization data at the TOAR-FUDS to meet RI/FS objectives.

9.2.1 Use of UXO Estimator

UXO Estimator was used during the site investigation at the TOAR-FUDS to address the issue of how to effectively characterize a range area without conducting either non-intrusive detection or intrusive sampling of the entire land area. UXO Estimator extrapolates the results of small sample areas to larger areas. During the RI, UXO Estimator was applied separately to Target Areas, Range Safety Fans, and Other Areas, in Park and in Game, to calculate the minimum number of acres to be investigated, with no UXO found, in order to meet a 95% confidence level that UXO density was less than 0.5 UXO/acre. After the RI was completed, and the CSM was revised, UXO Estimator was applied to Impact Areas, Buffer Zones, and Other Areas, in Park and in Game, to evaluate the data collected for a 95% confidence level that UXO density was less than 0.5 UXO/acre.

The applicability of UXO Estimator at the TOAR-FUDS depends on whether the areas being sampled are representative of the larger site. UXO Estimator assumes that a sector is homogeneous in terms of the likelihood of UXO being present. Because statistical sampling assumes an equal probability of detecting UXO in one location as in another, if the distribution of UXO is not truly homogeneous, the sampling methodologies could overlook UXO. Therefore, because the distribution of UXO in different areas at the TOAR-FUDS was probably not truly homogenous, the calculations made by UXO Estimator include a level of uncertainty.

9.2.2 MEC Investigation Technologies

As in any subsurface investigation, it is difficult to resolve all uncertainties. Regardless of the resources expended on an investigation, due to the existing limitations in detection technologies as they relate to depth, orientation, and geology, it is not possible to identify all MEC on a range. Likewise, unless the entire range is dug up, it is not possible to prove with certainty that the land area is clear and that no MEC is present.

Also, while the anomaly detection and analysis technologies were selected for this site because they were proven most effective and efficient, all detection technologies have inherent limitations, which may include low probability of detection and low ability to differentiate between MEC and/or fragments and background interference (objects or natural material not related to ordnance). These limitations create uncertain anomaly data, which can become magnified for two primary reasons:

- The areas suspected of containing MEC could contain terrain (hills, cliffs or swamps) or vegetation that interferes with 100% effective coverage of the entire area.
- Even within sectors suspected of containing MEC, it is often not practicable to excavate all detected anomalies during sampling to confirm whether they are in fact MEC. Excavation may be limited by vegetation, terrain or physical features (such as swamps).

9.2.3 Site Conditions

9.2.3.1 Environmental Conditions

The likelihood of locating and identifying MEC are affected by the past and future land uses, the types of munitions used and likely to be found, the depths at which MEC is suspected, and the soils and geology. Environmental conditions such as soil types (sand, clay) and geology (depth of bedrock) affect the depth and orientation at which munitions land on or beneath the ground surface. In addition, different types and sizes of munitions reach greater depths beneath the surface.

Site conditions at the TOAR-FUDS varied significantly across the site and over time. Some areas were physically inaccessible to UXO-qualifed personnel and/or detection equipment. Other areas, while perhaps physically accessible, contained other inherent health and safety risks that required they be excluded from the investigation. Some site conditions that limited access are shown in Figure 2-3 and included the following:

- Wetlands – Approximately 25% of site is covered by lakes, ponds, streams, and wetland, as can be seen in all investigation figures.
- Heavy woods – Approximately 80% of site is wooded.
- Boulder fields – Approximately 1-2% of the site consists of large boulder fields.
- Steep terrain.
- Thick brush.

9.2.3.2 Public Health and Safety

As described in Section 3 of the Work Plan, there were three principal munitions that were expected to be found at the TOAR-FUDS: 37-mm, the 75-mm and 155-mm. Therefore, there were multiple minimum separation distances (MSD) set for field work during this project. Of the artillery listed above, the MGFD is the 155-mm with a maximum fragmentation distance of 2,577 feet. The maximum fragmentation distance for the 155-mm was used to set the exclusion zone MSD within Impact Areas when UXO investigation or demolition activities were occurring. Areas not identified as impact areas observed a 200-foot MSD until the time an UXO item was found in that area. If that occurred, the MSD for that particular item was then observed. The development of MSDs for this project is described in detail in subsection 3.9 of the EE/CA Work Plan.

However, in the Lake Watawga area (AOC TOAR-1), UXO were found near the northern FUDS border within 500 feet of residential housing. Residential housing developments are currently approaching the FUDS border near the location. Because UXO were found within 500 feet of the housing, the MSD for impact areas could not be maintained in the Lake Watawga area, and intrusive investigation had to be halted indefinitely, thus preventing 100% investigation of identified DGM anomalies (potential UXO).

Also, in Game, once hunting season opened in the fall, because the full public access was maintained to the site, the MSD for impact areas could not be cleared or maintained. Therefore, intrusive investigation of impact areas and other areas of potential UXO contamination (buffer zones) in Game had to be halted, also preventing 100% investigation of identified anomalies.

Although certain areas were not investigated completely due to concerns regarding public health and safety, sufficient data was collected to adequately characterize those areas for the purposes of the RI/FS.

9.2.4 Environmental Sampling

A detailed uncertainty analysis of the data presented in the ecological risk assessment is provided in subsection 7.2.2.5. On a more general level, given the following factors, there is a level of uncertainty associated with the conclusions presented in subsection 7.2.2: that based on the screening analysis performed, neither explosives nor metals were detected at concentrations in soils, sediments or surface water in the TOAR-FUDS that are expected to pose an ecologically significant risk to plant and animal populations inhabiting these media:

- The magnitude of exceedances of ecological benchmarks for some metals – Some metals were detected at concentrations several orders of magnitude higher than ecological benchmarks.

- The spatial extent of potential contamination – The TOAR-FUDS consists of approximately 21,100 acres. Environmental sampling performed during the 2004 WESTON RI covered a very small percentage of the site (< 1%).
- The use of background data – No background study has been conducted for the TOAR-FUDS. Therefore, the assumption that contaminant levels within three times the reference background maximum concentrations presented in this RI report are within the expected levels of natural variability is not entirely supported.

Therefore, several chemicals (metals) that have been detected may pose low level ecological risk. As part of a risk management decision, additional environmental sampling for MC may be considered to ensure that the areas of exceedances are spatially limited and to verify the maximum contaminant levels identified to date.

9.2.5 Uncertainty Conclusions

There are inherent levels of uncertainty in MEC detection technologies and statistical models that cannot be avoided. The investigation techniques used at the TOAR-FUDS were shown to be the most effective and efficient during planning, during the geophysical prove-out, and during the site investigation. In addition, in many areas, site conditions prevented full access for and investigation with detection equipment, and maintaining public safety prohibited how much of the site could be intrusively investigated. These limitations create both real and apparent gaps in the field data. Real data gaps include lack of intrusive investigation due to public safety concerns (such as in AOC TOAR-1). Apparent data gaps may appear on a map as large areas that were not investigated, but where actual site conditions may have prevented field investigation in several areas (areas include Bender Swamp in Park, and areas surrounding Tobyhanna Creek and Bill Warner Spring in Game). Data gaps primarily affect the development of boundaries for the AOCs at the TOAR-FUDS. The fewer the data gaps, the more accurately the boundaries of the AOCs could be drawn. While the boundaries of the AOCs at the TOAR-FUDS could be refined, they are adequately identified for the purposes of an RI/FS. If the boundaries need to be refined to support the final remedial design, additional data could be collected as part of a focused FS or as part of the remedial design. Also, additional environmental sampling for MC may be considered, as part of a risk management decision, to ensure that areas of exceedances are spatially limited and to verify the maximum contaminant levels identified to date.

However, the CERCLA guidance for an RI states that the purpose of an RI is not to "remove all uncertainty but rather to gather information to support an informed risk management decision regarding the remedy which appears to be most appropriate for a given site" (EPA 540-G-89-0004, Para 1.1). Based on all the lines of evidence used to characterize the TOAR-FUDS, this RI contains an acceptable level of uncertainty and allows for an appropriate decision.

9.3 REMEDIAL INVESTIGATION CONCLUSIONS

The data collected during the RI supports the original CSM. UXO and MD were found in areas of expected contamination (Target Areas and Range Fans), and no UXO or MD were found in Other Areas, as expected. The original CSM was revised only slightly to account for historic artillery range layouts and varying densities of UXO and MD indicative of a UXO presence, but the original CSM was essentially unchanged. The agreement between the original CSM, data collected in the field, data collected during previous investigations, and the revised CSM confirms that the TOAR-FUDS is adequately characterized to meet the accuracy goals appropriate for a RI/FS (+50%/-30%), as stated in Section 9.2. Remedial alternatives for all nine AOCs will be evaluated in the FS.

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