FINAL
MMRP REMEDIAL INVESTIGATION REPORT

Remedial Investigation/Feasibility Study
Fort Hancock Formerly Used Defense Site
Monmouth County, New Jersey

Prepared for:

U.S. Army Corps of Engineers
Baltimore District

Contract: W912DR-09-D-0012, Delivery Order 0002

Prepared by:

ERT, Inc.

Laurel, Maryland 20707

(240) 554-0161

JANUARY 2014

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January 30, 2014

Attn: Julie Kaiser
CENAB-EN-HN
10 S. Howard Street
Baltimore, MD 21201-1715

Dear Ms Kaiser,

ERT, Inc., is pleased to present the Final Remedial Investigation Report for the Fort Hancock FUDS RI/FS, Monmouth County, NJ. This report was prepared under contract #W912DR-09-D-0012, DO 0002.

This version incorporates post-TPP meeting comments from the stakeholders.

Please do not hesitate to call me at 301-323-1442 if you need anything more.

Sincerely,

ELECTRONIC SIGNATURE

Thomas J. Bachovchin
Project Manager

DISTRIBUTION:

CENAB (Kaiser)
CENAN (Goepfert/Niaz)

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01/30/14

Thomas Bachovchin — Date

Project Manager

01/10/14

Jennifer Harlan — Date

Program Manager, PMP

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COMPLETION OF SENIOR TECHNICAL REVIEW

This document has been produced within the framework of the ERT, Inc. (ERT) quality management system. As such, a senior technical review has been conducted. This included review of all elements addressed within the document, proposed or utilized technologies and alternatives and their applications with respect to project objectives and framework of U.S. Army Corps of Engineers regulatory constraints under the current project, within which this work has been completed.

01/10/14

Jennifer Harlan Date
Senior Technical Reviewer

COMPLETION OF INDEPENDENT TECHNICAL REVIEW

This document has been produced within the framework of ERT's quality management system. As such, an independent technical review, appropriate to the level of risk and complexity inherent in the project, has been conducted. This included a review of assumptions; alternatives evaluated; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the project objectives. Comments and concerns resulting from review of the document have been addressed and corrected as necessary.

12/13/12

Barry Millman, PE Date
Independent Technical Reviewer

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ACRONYMS and ABBREVIATIONS

ALM	Adult Lead Model
APG	Aberdeen Proving Ground
APP	Accident Prevention Plan
AS	analytic signal
ASR	Archive Search Report
ATSDR	Agency for Toxic Substances and Disease Registry
BAF	bioaccumulation factor
BCF	bioconcentration factor
BGS	below ground surface
BIP	blow-in-place
BLRA	baseline risk assessment
BR	breeding population only
BSAF	biota-sediment accumulation factor
CD	compact disk
CENAB	U.S. Army Corps of Engineers, Baltimore District
CENAN	U.S. Army Corps of Engineers, New York District
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CO	Contracting Officer
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
CSF	cancer slope factor
CSM	conceptual site model
CTE	central tendency evaluation
CWM	chemical warfare materiel
DA	Department of the Army
DAF	dilution and attenuation factor
DDESB	Department of Defense Explosives Safety Board
DERP	Defense Environmental Restoration Program
DGM	digital geophysical mapping
DID	data item description
DMM	discarded military munitions
DoD	Department of Defense
DQA	data quality assessment
DOT	Department of Transportation
DQO	data quality objective
E	endangered
Eco-SSL	ecological soil screening level

ECRPP	Environmental and Cultural Resources Protection Plan
EE/CA	Engineering Evaluation/Cost Analysis
EFH	essential fish habitat
EM	Engineer Manual
EOD	Explosive Ordnance Disposal
EPC	exposure point concentration
ESP	Explosives Site Plan
EZ	exclusion zone
FFP	firm fixed price
FS	Feasibility Study
ft	feet
FUDS	Formerly Used Defense Site
GIS	Geographic Information System
GPO	geophysical prove-out
GPS	Global Positioning System
GSV	Geophysical System Verification
HAZWOPER	Hazardous Waste Operations and Emergency Response
HE	high explosives
HFD	hazard fragmentation distance
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
HRR	historical records review
HTW	hazardous and toxic waste
Hz	hertz
IDLH	immediately dangerous to life or health
IDW	investigative derived waste
IEUBK	integrated exposure biokinetic uptake
ILCR	incremental lifetime cancer risk
in	inch
INPR	Inventory Project Report
IRIS	Integrated Risk Information System
IS	incremental sample
ISO	industry standard objects
IUR	inhalation unit risk
IVS	Instrument Verification Strip
J	estimated
JFK	John F. Kennedy Airport
kg	kilogram
LOAEL	lowest observed adverse effects level
LOEC	lowest observed effects concentration

LT	formerly listed as threatened
LUC	land use control
m	meter
MAMMS	Multiple-Award Military Munitions Services
MC	munitions constituents
MCL	maximum contaminant level
MEC	munitions and explosives of concern
MD	munitions debris
MDAS	material documented as safe
MDEH	material documented as an explosive hazard
MFD	maximum fragmentation distance
mg/kg	milligram per kilogram
mg/L	milligram per liter
MGFD	munition with the greatest fragmentation distance
mm	millimeters
MM	military munitions
MMRP	Military Munitions Response Program
mph	miles per hour
MPPEH	material potentially presenting an explosive hazard
MRA	Munitions Response Area
MRS	Munitions Response Site
MRSPP	Munitions Response Site Prioritization Protocol
MSD	minimum separation distance
MSDS	Material Safety Data Sheet
NA	not applicable
NB	non-breeding population only
NCP	National Contingency Plan
NELAP	National Environmental Laboratory Accreditation Program
NEW	net explosive weight
NFA	no further action
NGVD	National Geodetic Vertical Datum
NIOSH	National Institute for Occupational Safety and Health
NJDEP	New Jersey Department of Environmental Protection
NJMSC	New Jersey Marine Sciences Consortium
NOAA	National Oceanographic and Atmospheric Administration
NOAEL	no observed adverse effect levels
NPL	National Priorities List
NPS	National Park Service
nT	nanoTesla
OECert	Ordnance and Explosives Cost-Effectiveness Risk Tool
OESS	Ordnance and Explosives Safety Specialist

OEW	ordnance and explosive waste
OSWER	Office of Solid Waste and Emergency Response
PAOI	potential area of interest
PARCCS	precision, accuracy, representativeness, comparability, completeness, and sensitivity
PDT	Project Delivery Team
PEF	particulate emission factor
PEL	permissible exposure limit
PETN	pentaerythritol tetranitrate
PID	photoionization detector
PM	Project Manager
PMP	Project Management Plan
PPE	personal protective equipment
PPP	Public Protection Plan
QA	quality assurance
QAPP	Quality Assurance Project Plan
QASP	Quality Assurance Surveillance Plan
QC	quality control
Q-D	quantity-distance
QCM	Quality Control Manager
QCP	Quality Control Plan
RAC	risk assessment code
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RDX	Royal Demolition Explosive (cyclotrimethylenetrinitramine)
RfC	reference concentration
RfD	reference dose
RI	Remedial Investigation
RL	reporting limits
RME	reasonable maximum exposure
RSL	regional screening level
RTS	robotic total station
RTK GPS	Real Time Kinematic Global Positioning System
SI	Site Inspection
SLERA	screening level ecological risk assessment
SOP	standard operating procedure
SOS	Spencer Oceanographic Survey
SPLP	synthetic precipitate leaching procedure
SSL	soil screening level
SUXOS	Senior UXO Supervisor

SVOCs	semi-volatile organic compounds
SZ	support zone
T	threatened
TAL	target analyte list
TBC	to be considered
TBD	to be determined
TCLP	Toxicity Characteristic Leaching Procedure
TD	Technical Director
TE	Technical Escort
TNT	trinitrotoluene
TOC	top of casing
TPP	Technical Project Planning
TVG	G-882 transverse gradiometer
UCL	upper confidence level
UFP-QAPP	Uniform Federal Policy Quality Assurance Project Plan
USACE	U.S. Army Corps of Engineers
USATCES	U.S. Army Technical Center for Explosives Safety
USC	United States Code
USDOT	U.S. Department of Transportation
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
UXO	unexploded ordnance
UXOQCS	UXO Quality Control Specialist
UXOSO	UXO Safety Officer
V	volt
VOCs	volatile organic compounds
VSP	Visual Sample Plan
WGS	World Geodetic System
µg/L	micrograms per liter
µg/dL	micrograms per deciliters

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GLOSSARY OF TERMS

Anomaly Avoidance – Techniques employed on property known or suspected to contain unexploded ordnance (UXO), other munitions that may have experienced abnormal environments (e.g., discarded military munitions [DMM]), munitions constituents (MC) in high enough concentrations to pose an explosive hazard, regardless of configuration, to avoid contact with potential surface or subsurface explosive hazards, to allow entry to the area for the performance of required operations.

Cultural Debris – Debris found on operational ranges or munitions response sites (MRSs), which may be removed to facilitate a range clearance or munitions response, that is not related to munitions or range operations. Such debris includes, but is not limited to, rebar, household items (refrigerators, washing machines, etc.), automobile parts and automobiles that were not associated with range targets, fence posts, and fence wire. Cultural debris does not refer to items of cultural or historical significance.

Defense Site – All locations that are or were owned by, leased to, or otherwise possessed or used by the DoD. The term does not include any operational range, operating storage or manufacturing facility, or facility that is used or was permitted for the treatment or disposal of military munitions.

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 [USC] 2710(e)(2)).

Explosive Hazard – A condition where danger exists because explosives are present that may react (e.g., detonate, deflagrate) in a mishap with potential unacceptable effects (e.g., death, injury, damage) to people, property, operational capability, or the environment.

Explosive Ordnance Disposal (EOD) – The detection, identification, on-site evaluation, rendering safe, recovery, and final disposal of unexploded ordnance and of other munitions that have become an imposing danger, for example, by damage or deterioration.

Explosive Ordnance Disposal (EOD) Unit – A military organization constituted by proper authority, manned with EOD personnel, outfitted with equipment required to perform EOD functions, and assigned an EOD mission.

Explosives Safety – A condition where operational capability and readiness, people, property, and the environment are protected from the unacceptable effects or risks of potential mishaps involving military munitions.

Material Potentially Presenting an Explosive Hazard (MPPEH) – Material potentially containing explosives or munitions (e.g., munitions containers and packaging material; munitions debris (MD) remaining after munitions use, demilitarization, or disposal; range-related debris); or material potentially containing a high enough concentration of explosives such that the materia1 presents an explosive hazard (e.g., equipment, drainage systems, holding tanks, piping, or ventilation ducts that were associated with munitions production, demilitarization or disposal operations). Excluded from MPPEH are munitions within DoD's 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.

Military Munitions – Military munitions means all ammunition products and components produced for or used by the armed forces for national defense and security, including ammunition products or components under the control of the DoD, the Coast Guard, the Department of Energy, and the National Guard. The term includes confined gaseous, liquid, and solid propellants; explosives, pyrotechnics, chemical and riot control agents, smokes, and incendiaries, including bulk explosives, and chemical warfare agents; chemical munitions, rockets, guided and ballistic missiles, bombs, warheads, mortar rounds, artillery ammunition, small arms ammunition, grenades, mines, torpedoes, depth charges, cluster munitions and dispensers, demolition charges; and devices and components thereof. The term does not include wholly inert items; improvised explosive devices; and nuclear weapons, nuclear devices, and nuclear components, other than nonnuclear components of nuclear devices that are managed under the nuclear weapons program of the Department of Energy after all required sanitization operations under the Atomic Energy Act of 1954 (42 U.S.C. 201 1 et seq.) have been completed. (10 U.S.C. 101(e)(4)(A) through (C)).

Munitions and Explosives of Concern (MEC) – This term, which distinguishes specific categories of military munitions that may pose unique explosives safety risks means (A) UXO, as defined in 10 U.S.C. 101(e)(5); (B) DMM, as defined in 10 U.S.C. 2710(e)(2); or (C) MC (e.g., Trinitrotoluene [TNT], Cyclotrimethylenetrinitramine [RDX]), as defined in 10 U.S.C. 2710(e)(3), present in high enough concentrations to pose an explosive hazard.

Munitions Constituents (MC) – Any materials originating from UXO, DMM, or other military munitions, including explosive and nonexplosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions. (10 U.S.C. 2710(e)(3)) **.**

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

Munitions Response – Response actions, including investigation, removal actions and remedial actions to address the explosives safety, human health, or environmental risks presented by UXO, DMM, or MC, or to support a determination that no removal or remedial action is required.

Munitions Response Area (MRA) – Any area on a defense site that is known or suspected to contain UXO, DMM, or MC. Examples include former ranges and munitions burial areas. An MRA is composed of one or more MRSs.

Munitions Response Site (MRS) – A discrete location within an MRA that is known to require a munitions response.

Operational Range – A range that is under the jurisdiction, custody, or control of the Secretary of Defense and that is used for range activities or, although not currently being used for range activities, that is still considered by the Secretary to be a range and has not been put to a new use that is incompatible with range activities. (10 U.S.C. 101(e)(3)(A) and (B)). Also includes "military range," "active range," and "inactive range" as those terms are defined in 40 Code of Federal Regulations §266.201.

Range – A designated land or water area that is set aside, managed, and used for range activities of the DoD. The term includes firing lines and positions, maneuver areas, firing lanes, test pads, detonation pads, impact areas, electronic scoring sites, buffer zones with restricted access, and exclusionary areas. The term also includes airspace areas designated for military use in accordance with regulations and procedures prescribed by the Administrator of the Federal Aviation Administration. (10 U.S.C. l0l (e)(l)(A) and (B)).

Unexploded Ordnance (UXO) – Military munitions that (A) have been primed, fuzed, armed, or otherwise prepared for action; (B) have been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material; and (C) remain unexploded whether by malfunction, design, or any other cause. (10 U.S.C. 101(e)(5)(A) through (C))

Unexploded Ordnance (UXO)-Qualified Personnel – Personnel who have performed successfully in military EOD positions or are qualified to perform in the following Department of Labor, Service Contract Act, Directory of Occupations, contractor positions: UXO Technician II, UXO Technician III, UXO Safety Officer, UXO Quality Control Specialist, or Senior UXO Supervisor.

Unexploded Ordnance (UXO) Technicians – Personnel who are qualified for and filling Department of Labor, Service Contract Act, Directory of Occupations, contractor positions of UXO Technician I, UXO Technician II, and UXO Technician III.

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EXECUTIVE SUMMARY

Introduction and Scope

ERT, Inc. (ERT), performed a Remedial Investigation (RI) for the United States Army Corps of Engineers (USACE), at the Fort Hancock Formerly Used Defense Site (FUDS), located in Monmouth County, New Jersey. The work was performed as a performance-based firm fixed price (FFP) task order under the Multiple-Award Military Munitions Services (MAMMS) Contract (W912DR-09-D-0012, Delivery Order 0002), which is administered by the Baltimore District (CENAB), and for which technical oversight is provided by Baltimore District.

The purpose of this RI is to adequately characterize the nature and extent of any potential munitions constituents (MC) contamination or munitions and explosives of concern (MEC) hazards resulting from the past use of Fort Hancock. The scope of the RI included digital geophysical mapping (DGM), intrusive investigations to identify location, density, and types of MEC, and environmental sampling to determine the distribution and concentrations of metals and explosives in soil, sediment, surface water, and groundwater.

Fort Hancock is located on the Sandy Hook peninsula in Monmouth County, New Jersey. The Former Fort Hancock occupied most of the peninsula, which encompasses approximately 1,700 acres, is known as the Sandy Hook Unit of the Gateway National Recreation Area, and is a National Historic Landmark. It is currently managed by the Department of the Interior (National Park Service [NPS]) and the U.S. Coast Guard, and is used for a variety of recreational purposes year-round.

Items that were potential MEC have been found at Fort Hancock, including in the waters off the eastern coast of the peninsula. The majority of the Fort Hancock acreage is highly trafficked by the public, including fishing and swimming activities. Although there have previous investigations and MEC removals from Fort Hancock in the past, any remaining MEC may present an imminent and substantial endangerment to human health and the environment; this RI was commissioned in order to identify areas where MEC or MC remain, to identify risk, and to recommend further actions, if necessary.

Investigation Activities

MRS Development

Because of the complex site history and lack of concise historic documents and maps outlining the areas where munitions was tested or fired, the munitions response site (MRS) configurations have changed from one previous investigation to the next, and subsequent review of the site history for this RI resulted in revised MRS configurations relative to those presented in the 2007 Site Inspection (SI) Report. The MRSs investigated in this RI are based on the former locations of proving ground impact areas identified in a historic report (Ordnance History – Fort Hancock (1874-1919) that were not specifically incorporated into previous investigations. Primarily using the impact areas and working back toward the firing points, range fans areas were developed into the six MRS boundaries (MRS-1 through MRS-6).

The impact area locations are thought to more accurately represent areas where MEC may remain from historic military operations. The Livens Discovery Area was developed into its own MRS (MRS-7) reflecting heightened interest from stakeholders based on the historic discovery of Livens projectiles, which were incorrectly associated with chemical warfare materiel (CWM) in the 1993 Archives Search Report (ASR).

In addition to these seven MRSs, in response to concerns from the New Jersey Department of the Environment (NJDEP) that more former batteries should be included in the RI, two Potential Areas of Interest (PAOIs), containing several former batteries, were also investigated.

MRS-8 is the water investigation component of the RI. MRS-8 was developed through discussion with USACE. The footprint of MRS-8 parallels the coastline, beginning at the northern edge of MRS-1 and extending southward to the southern edge of land MRS-6, projecting out into the Atlantic Ocean for approximately 100 yards. The eastern extent of MRS-8 is based on the likely maximum depth of 6 feet for human receptors to encounter MEC through wading or swimming activities.

MC

Environmental sampling of soil, surface water, sediment, and groundwater for MC was completed. Incremental samples (IS) soil samples associated with blow-in-place (BIP) activities were collected. Based on concerns from NJDEP, and to ensure that the Livens Discovery Area (MRS-7) was thoroughly characterized, a random surface soil sampling approach (discrete grab samples) was developed to support a statistical comparison to applicable screening standards for those chemicals. Surface water and co-located sediment samples were also collected from Nike Pond (located within MRS-5) to assess surface water run-off. Finally, groundwater samples were collected from five existing monitoring wells located at various areas throughout Fort Hancock.

MEC/MD

The RI activities to evaluate MEC and munitions debris (MD) presence included a comprehensive statistically-based DGM and intrusive investigation of land-based MRSs was conducted. DGM was conducted on 38 miles of transects, 87 grids (16.68 acres), and nearly 5,000 anomalies were intrusively investigated.

In addition to the land-based MRSs, a comprehensive statistically-based DGM and intrusive investigation of marine-based MRS-8 was conducted, including approximately 71,020 linear feet or 9.4 miles of usable data acquired, covering approximately 9 acres. In MRS-8, 51 anomalies were intrusively investigated.

Investigation Findings

MC

IS soil samples associated with blow-in-place (BIP) activities were analyzed for metals and explosives. No explosives compounds above the detection limits were found in any sample. Various metals were detected, but none of the metals were found at levels inconsistent with background concentrations. Analysis of soil samples from MRS-7 found no explosives compounds above the detection limits in any sample. Various metals were detected, but none of the metals were found at levels inconsistent with background concentrations. A “hot spot” analysis of soil sample results indicated the absence of potential contamination that could pose a threat to the underlying groundwater. Based on this evaluation, the need for an expanded groundwater investigation was not indicated.

Groundwater samples from existing wells were analyzed for metals and explosives. No explosives compounds were found above the detection limits in any sample. Various metals were detected in the groundwater but were determined to be within the background ranges for those metals.

Surface water and co-located sediment samples from Nike Pond (MRS-5) were analyzed for metals and explosives. No explosives compounds were found above the detection limits in any sample. Various metals were detected. While some metals were above ecological screening criteria, no ecological risks were identified in the risk assessment.

MEC/MD

Seven MEC items and 65 munitions debris (MD) items were found in the land-based MRSs. Some of these items were found on the surface and some were found in the subsurface. No MEC or MD were found in marine MRS-8.

The results of the DGM and intrusive investigations indicate that certain areas containing a concentration of metallic anomalies (clusters) within the MRSs have a higher likelihood of a human or ecological receptor encountering MEC or MD than others. In these clusters, MEC/MD Hazard Areas were identified as areas of focus within the MRS. These MEC/MD Hazard Areas provide an approach to reducing the overall MRS footprint for potential future actions. As defined, the MEC/MD Hazard Areas represent a “moderate to high” probability of encountering MEC/MD, while the remainder of the MRS represents a “low” probability of encountering MEC/MD. Note that based on the statistical design of the investigation, areas categorized as “low probability”, where no MEC or MD was found, and where the coverage goal was not achieved, could still contain MEC or MD items. However, there were few of those areas, as discussed in Section 5.2.2.

Table ES-1 summarizes the MEC/MD Hazard Areas per location. All other MRSs and the other PAOI were determined to represent a low probability of encountering MEC/MD. The analysis of these findings is presented in Section 5.2 and Tables 5-7 and 5-8.

Table ES-1. MEC/MD Hazard Areas

MRS	NPS Excluded Acreage	MEC/MD Hazard Area	Probability of Encountering MEC/MD
MRS-1	1.4	1A*	Moderate to High
		1B	Moderate to High
MRS-2	15.5	2A	Moderate to High
MRS-3	3.5	3A	Moderate to High
		3B	Moderate to High
MRS-4	25.7	4A	Moderate to High
MRS-5	86.5	5A	Moderate to High
		5B	Moderate to High
PAOI-9 Gun	None	PAOI-9 Gun-A	Moderate to High

* Includes the B003 Area.

The B003 Area within MEC/MD Hazard Area 1-A of MRS-1, represents an additional area of focus within 1A. During the USACE 1998 Engineering Evaluation/Cost Analysis (EE/CA) investigation, several MEC items were found in grid B003; however, not all of the anomalies, some of which may have been MEC, were excavated. The EE/CA described this area as an ordnance disposal area, recommending a removal action. The intent of the RI effort for the B003 Area was to determine the extent of the B003 EE/CA grid by excavating all anomalies found on the closely spaced transects. Only MD was found in the B003 Area during this RI (no MEC). While MD is scattered around the EE/CA B003 grid, the MEC items from the EE/CA investigation are limited to the eastern half of grid B003, and that appears to be the extent of MEC contamination associated with this previously defined disposal area.

Approximately 83% (24.2 of 29 acres) of MRS-7 was excluded from investigation by NPS, and could not be investigated in a systematic way. This lessened the ability to provide the statistically supported conclusions related to this MRS, and therefore, no conclusions can be drawn about the presence or absence of MEC or MD in the MRS-7 areas denied access by NPS.

This also applied to other areas excluded from investigation by NPS. That is, where little or no DGM coverage was obtained, no conclusions can be drawn about the presence or absence of MEC or MD in the areas denied access by NPS.

In addition to the findings of the RI activities, munitions-related items were also encountered during the 1998 EE/CA. Those findings are discussed in more detail in Section 5.2.2.11 to provide the relevance of the findings with regard to presenting a more complete picture of MEC and/or MD at the site. Further, it is acknowledged that there is the potential for MEC and/or MD to be found anywhere on the Sandy Hook peninsula as a result of the length of time that has passed since the proving ground closed and the effects of the dynamic environment (for example, storms, shoreline erosion, shifting sand dunes) over time.

Risk Assessment

Human health and ecological risk assessments, which pooled the RI sampling data with the 2007 SI sampling data, were conducted. The human health risk assessment evaluated the current and potential future exposure of receptors to site media and concluded that soil at MRS-1, MRS-3, MRS-5, MRS-6, and MRS-7 does not pose a threat to human health. The sediment and surface water at Nike Pond (within MRS-5) does not pose a threat to human health. At the B003 Area (within MRS-1), arsenic and lead in soil could potentially pose a threat to human health. However, these conclusions are based largely on a single soil sample (out of 3 samples collected from the B003 Area as part of the SI in 2006) that contained the maximum detections of these metals.

Evaluation of the IS data associated with BIP activities indicated detections of metals in the vicinity of the BIP locations, but the potential contaminants did not pose a threat to human health based on comparison to the residential soil RSLs.

There were two groundwater chemicals of potential concern (COPCs): arsenic and manganese. The manganese did not pose a threat to human health. For arsenic, a risk management decision of no further action with respect to the groundwater is justified based on the fact that the maximum detection was from a single well located in an area where arsenic was at background levels, the concentrations in groundwater were consistent with the range of typical arsenic concentrations in groundwater in New Jersey, and the shallow groundwater is not currently used for any purpose (future use of the shallow groundwater as a potable water supply is extremely unlikely). The single well used for potable water is approximately 880 feet deep, and has tested safe for consumption, with manganese concentrations in the inlet water pipe sufficiently removed in the treatment process.

The ecological risk assessment evaluated potential risks to terrestrial, benthic invertebrate, and aquatic receptors that might contact the site soil, sediment, and surface water. No ecological threats were identified for MRS-1, MRS-3, MRS-5, MRS-6, MRS-7, and Nike Pond. At the B003 Area, based largely on one soil sample, antimony, copper, lead, and selenium could pose a threat to wildlife receptors. In addition, based on the same soil sample, antimony, arsenic, copper, lead, and thallium contamination at the B003 Area may pose a threat to the plant and/or soil invertebrate communities.

In accordance with the approved Work Plan approach, no environmental samples were collected during the RI in MRS-2, MRS-4, and MRS-8, because no breached MEC, visible evidence of energetics, or areas of significant MD were encountered. No samples were collected in these areas during the 2007 SI. Therefore, no quantitative risk assessment was performed for these MRSs. However, groundwater findings, as discussed above, apply to the entire site.

<u>Conclusions</u>

Nature and extent of MC and MEC at Fort Hancock has been characterized. Human health and ecological risks have been assessed. Areas of focus (MEC/MD Hazard Areas) have been delineated based on MEC/MD densities. Table ES-2 presents the RI findings, summarizing conclusions with regard to MC risks and MEC/MD hazards present at the site.

In addition, the potential human health and ecological risks posed by MC found in the B003 Area soil may warrant additional investigation. It is recommended that additional soil sampling be conducted to determine the extent and source of metals contamination in this area.

With regard to the portion of MRS-7 that was excluded by NPS and could not be fully investigated, based on the site history (former storehouse that contained the Livens projectiles and caught fire in 1927), it is recommended that the NPS excluded portion (24.2 of 29 acres) be further investigated using DGM and anomaly excavations to determine the nature and extent of MEC/MD, and to identify possible MEC/MD Hazard Areas.

Finally, please note that the need for additional soil sampling at B003 will be addressed in an Addendum to this RI report. The Addendum will evaluate the new sample data and revise the human health and ecological risk assessments of the B003 area, as appropriate.

USACE has further determined that this Addendum will be the appropriate document to present the Munitions Response Site Prioritization Protocol (MRSPP) evaluations and MEC Hazard Assessments (MEC HA). The MRSPP is a required tool used by the Department of Defense to rank sites for further action. The MEC HA is a tool used to assess potential explosive hazards to human receptors at the MRSs. These evaluations will be conducted for revised MRSs that will be delineated based on the results of the RI.

Note: This report presents the results of investigations completed in the winter and fall of 2011 and reflects the conditions at that time. It is acknowledged that any potential impacts to the site resulting from the October 2012 Super Storm Sandy will be considered and assessed in the process of evaluating the need for future actions at the site.

Table ES-2. Summary of Findings

MRS	MEC/MD Hazard Area or Area of Focus	Acreage		MEC Density (item/acre)	Potential Concern	
		Total MRS	Area of Focus		MC	MEC/MD\1
MRS-1	B003 Area	99	2.24	NA	Metals in Soil for Human and Ecological Receptors	\2
	1A		28.89	19.76	None	Moderate to High
	1B		1.51	1.97	None	Moderate to High
MRS-2	2A	151	39.0	2.03	None	Moderate to High
MRS-3	3A	89	0.92	3.26	None	Moderate to High
	3B		1.07	3.41	None	Moderate to High
MRS-4	4A	73	5.15	5.93	None	Moderate to High
MRS-5	5A	205	3.92	1.49	None	Moderate to High
	5B		2.15	8.23	None	Moderate to High
MRS-6	None	90	NA	NA	None	Low
MRS-7	NPS Excluded Portion\3	29	24.2	\3	None	\3
	Investigated Portion\4		4.8	NA	None	Low
MRS-8	None	154	NA	NA	None	Low
PAOI 9 Gun	PAOI-9 Gun-A	8.45	1.19	NA	None	Moderate to High
PAOI Kingman-Mills	None	19.45	NA	NA	None	Low

\1 – Probability of encountering MEC/MD

\2 – MEC risk driver for B003 included in MEC/MD Hazard Area-1A

\3 – This portion of MRS-7 could not be fully investigated for MEC/MD presence due to significant NPS excluded acreage. However, it was fully investigated for MC.

\4 – This portion of MRS-7 was fully investigated

1.0 INTRODUCTION

ERT, Inc. (ERT), performed a Remedial Investigation (RI) for the United States Army Corps of Engineers (USACE), at the Fort Hancock Formerly Used Defense Site (FUDS), located in Monmouth County, New Jersey. The work was performed as a performance-based firm fixed price (FFP) task order under the Multiple-Award Military Munitions Services (MAMMS) Contract (W912DR-09-D-0012, Delivery Order 0002), which is administered by the Baltimore District (CENAB), and for which technical oversight is provided by Baltimore District.

This project falls under the Military Munitions Response Program (MMRP) of the Defense Environmental Restoration Program/Formerly Used Defense Sites (FUDS). The Department of Defense (DoD) established the MMRP under the DERP to address munitions constituents (MC), munitions and explosives of concern (MEC) (comprising unexploded ordnance [UXO], discarded military munitions [DMM], and MC in high enough concentrations to pose an explosive threat) that are located on current and former military installations. MEC are a safety hazard and may constitute an imminent and substantial endangerment to site personnel and the public. ERT performed all work in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 104 and the National Contingency Plan (NCP), Sections 300.120(d) and 300.400(e). Applicable provisions of Chapter 29 of the Code of Federal Regulations (CFR) 1910.120 apply. All activities involving work in areas potentially containing MEC hazards was conducted in full compliance with USACE, Department of the Army (DA), and DoD safety regulations. All MEC that was encountered during this munitions response was destroyed on-site or appropriately disposed of under “Safe to Handle” procedures.

The Project Team consisted of ERT, CENAB and USACE New York District (CENAN), as well as other government and non-government agencies with specific expertise for implementation of specialized components of the field operations. For purposes of this RI Report CENAB and CENAN are referred to jointly as “USACE”, unless specific district responsibilities are discussed.

1.1 Purpose and Scope

The purpose of this RI is to adequately characterize the nature and extent of any potential MC contamination or MEC hazards resulting from the past U.S. military use of Fort Hancock. The areas suspected of containing MEC and MC hazards (Munitions Response Sites [MRSs]) that were investigated during the 2007 Site Inspection (SI) are described in Section 1.2.1 below. USACE changed all but one of the MRS designations for the RI to focus the investigation on areas better documented as having been used for munitions testing. These changes are explained in Section 1.2.2.

The scope of the RI included digital geophysical mapping (DGM), intrusive investigations to identify location, density, and types of MEC, and environmental sampling to determine the nature and extent of metals and explosives compounds in soil, sediment, surface water, and groundwater.

1.2 Property Description and Problem Identification

Fort Hancock is located on the Sandy Hook peninsula in Monmouth County, New Jersey, in the Lower Bay of the Hudson River. Raritan Bay is north of Fort Hancock, Sandy Hook Bay borders the site on the west, and the Atlantic Ocean is east of the peninsula. The peninsula, which encompasses approximately 1,700 acres, is known as the Sandy Hook Unit of the Gateway National Recreation Area and is a National Historic Landmark. It is currently managed by the Department of the Interior (National Park Service [NPS]) and the U.S. Coast Guard, and is used for a variety of recreational purposes year-round. An active U.S. Coast Guard Station is positioned on the northwest corner of the peninsula (approximately 68 acres). The closest city is Highlands, located on the mainland of New Jersey, south of the peninsula. Figure A-1-1 presents the project location on a U.S. Geological Survey (USGS) 7.5-minute topographic map.

MEC and munitions debris (MD) have been found at Fort Hancock over the years, primarily by the NPS as well as USACE during environmental investigations. Most of the Fort Hancock acreage is highly trafficked by the public. MEC and MD have been found on the eastern beaches after storm events and are thought to have originated off-shore; park visitors use the eastern beaches for fishing and swimming. MEC, where present, may constitute an imminent and substantial endangerment to the public and the environment. Access to these items and removal by unauthorized personnel is also a concern. Table 1-1 lists munitions types documented as having been used at Fort Hancock or having been found at Sandy Hook.

1.2.1 SI MRS Delineations

The 2007 SI was conducted on six MRSs that are based on the 1993 USACE Archives Search Report (ASR) and 2004 ASR Supplement, which are discussed in Section 1.4 below. These MRSs have been reported in annual reports to DoD and Congress and have not been officially modified since they were entered in the FUDS Management Information System (FUDSMIS) in 2000. The six MRSs are described below and shown in Figure A-1-3. The acreages are those that were approved for further investigation; however, upon further evaluation and research for RI scoping, it became apparent that many of the MRSs did not accurately reflect areas suspected of containing MEC. As a result, the MRSs were significantly revised for purposes of conducting the RI, as described in the paragraphs following the list and in Section 1.2.2.

- MRS 1, Southern Dredging Disposal Area. 31 acres on southern portion of property where beach replenishment operations were said to have resulted in munitions and debris being deposited on the beach.
- MRS 2, Livens Projectile Disposal Area. 24 acres in central portion where Livens projectiles were found in 1981 and a disposal area for chemical warfare materiel (CWM) was suspected, as the projectiles contained liquid filler.
- MRS 3, Northern Disposal Area. Presumed 1-acre off-shore area where fragmentation grenades were said to have been dumped.
- MRS 4, CWM Research and Development Laboratory. Presumed CWM testing lab based on historical report identifying Building 109 as a chemical lab and record that phosgene gas was stored at the property.
- MRS 5, Northern Battery Complex. 356 acres on land and 130,580 acres off-shore, consisting of overlapping range fans associated with 13 gun batteries on northern portion of property. Includes the “Northern Proving Ground” (boundaries estimated).
- MRS 6, Hand Grenade Court. Zero-acre area (because location is unknown), to represent potential hand grenade training area. Based on an assumption that grenade training took place.

Table 1-1. Munitions Types at Sandy Hook

Item Description	Comments
Small Arms, General	Munitions listed in the ASR Supplement, 2004; based on handwritten ledger of NPS finds included in 1993 draft Archives Search Report (ASR was finalized in 2006)
75mm, Chemical, M64	
90mm, AP, M77	
90mm, HE M71	
105mm, HE, M1	
155mm, HE, Mk1	
155mm, Propelling Charge, M3	
3-inch projectile	
3-inch, HE, M1915	
4.7-inch projectile	
5-inch projectile (5-inch Common, Mk15)	
6-inch, AP (Shell), M1911	
6-inch, AP, Model 1911	
7-inch, HE projectile (LIVE)	
8-inch, HE, M105	
8-inch, HE, M106	
10-inch projectile	
12-inch, AP, M1912	
12-inch, AP, M1913	
12-inch, AP, Mk 18	
16-inch, AP, Mk5	
Civil War Smoothbore Projectiles (10-inch, 12 pounder, 15-inch)	
Coast Artillery (Early 1900's)	
Hand Grenades (LIVE)	
MkII, Hand Grenade, Fragmentation (LIVE)	
Rifle Grenades (WWII and other)	
Smoke Grenades	
M1A1 Smoke Dispensers	
Rocket, 2.36 inch HEAT, M6A1	
Rocket, 2.36 inch HEAT, M71A1	
Livens Projector Shell, Mk2	
Livens Projector Shell, Mk21	
Live Mk V fuze	
Stokes Mortar Fuzes	
Torpedo, General	

Table 1-1. Munitions Types at Sandy Hook

Item Description		Comments
75mm projectile (2)	Categorized as "conventional UXO containing explosive charges" in the EE/CA	1998 EE/CA Finding (UXO/OE)
Live Mark V fuze		
5-inch shrapnel round		
7-inch, HE projectile (LIVE)		
3-inch projectile (3)		
10-inch projectile (3)		
8-inch projectile		
4.7-inch projectile (10)		
5-inch projectile		
6-inch projectile (2)		
12-inch projectile (2)		
Stokes Mortar Fuzes		
Livens projectile (FM smoke)		
MK1, 1-lb, 1.44-inch round		2011 RI Finding (MEC)
3.5-inch projectiles		
4.5-inch Mark V British AP HE round		
5-inch AP, HE projectile, 18-inch length		
75mm projectiles (2)		
3-inch Stokes Mortar		

For purposes of scoping the RI, USACE researched the six MRSs to determine which should be included in the study. During follow-up discussions with NPS, it was discovered that some the MRSs were based on anecdotal information obtained during the ASR interviews. The primary employee interviewed, a cultural resource management specialist, had approximated some of the areas from his recollections of site history and NPS munitions finds; later, he could not confirm the existence of MRSs 3 and 6. The assumption of a grenade training area on Plum Island (MRS 6) was apparently based on a statement made during the ASR interview that grenades had been found there and that grenade training had taken place somewhere at Fort Hancock. However, the employee said this was based on the recollection of one WWII veteran, who was probably wrong because no historical records of the area and no MEC items of any kind were found there (USACE, 2009a). In a separate conversation, the employee said he could not recall the existence of MRS 3, Northern Disposal Area, and that it might have been based on items that had washed up on the northwestern shore of the peninsula. The presence of these two MRSs is considered speculative, and they were therefore excluded from the RI.

For MRS 1, NPS confirmed that munitions items were brought onto the southern tip of the peninsula in 1982 during a beach replenishment project, but the beach was subsequently washed out and the items were swept out to sea as well. The beach was replenished again in 1990 and another time in 1997, and no MEC or MD was found (USACE, 2009a). Although this is no longer a MEC dredge disposal area, the area was encompassed by RI MRS 6 upon discovery of information about proving ground targets (see 1.2.2 below).

MRS 2 was retained for the RI (renamed MRS-7), as documentation of the Livens projectiles exists in site records and the 1998 Engineering Evaluation/Cost Analysis (EE/CA) (see Section

1.4.4). However, USACE conducted a probability assessment in 2008 as follow-up to the 2007 SI and determined that it is unlikely that CWM will be encountered at Fort Hancock. The assessment was based on the lack of records of any CWM testing, disposal, or storage and documentation obtained from the U.S. Army 22nd Chemical Battalion Technical Escort (TE) regarding the contents of the Livens projectiles. Although the projectiles found in 1981 (and subsequently during the EE/CA) contained a liquid filler, the material was found to be titanium tetrachloride (FM smoke), which is not classified as CWM (USACE, 2008). The New Jersey Department of Environmental Protection (NJDEP) concurred with the probability assessment and the recommendation that the RI proceed as a conventional MMRP project (NJDEP, 2008).

For MRS 4, USACE could not find documentation that the building was used for CWM research or development. Further, the 2008 probability assessment deemed it unlikely that CWM would be encountered at the property. During the SI, soil samples were collected around the building and contained no elevated concentrations of MC. To further research the potential for CWM in this building, USACE gained access to the abandoned Building 109 for a visual inspection (the interior had not previously been inspected). NPS presented an excerpt from a report entitled *Historic Structure Report, Architectural Data Section (Volume IV)*, dated Aug. 25, 1988, in which Bldg. 109 is referred to as the "School/Chemistry Laboratory [Structure No. 109 (22)], Built 1904." The lab was the setting for the Ordnance School of Application in which student ordnance officers conducted lab investigations of the action of smokeless powder. In 1908, the electrical laboratory was transferred into the building, and all chemical equipment was transferred to Picatinny Arsenal. In 1935, the building was vacated by the artillery engineers so that it could become the post school. The report mentions nothing about CWM testing; it was concluded that the building was inaccurately named in the ASR (NPS, 1988). NPS also provided a copy of a 1918 map on which the building (then numbered 22) is labeled "Chemical and Electrical Laboratory" (Ordnance Dept USA, 1918). USACE noted no hazards inside the building during the 2009 visit and subsequently eliminated this MRS from the RI based on the absence of documentation of MEC or MC hazards (USACE, 2009b).

A portion of MRS 5 was retained (the "Northern Proving Ground"), as documentation of the firing points and impact areas for the entire proving ground was later found and encompassed this area (see MRS-1 and 2 below). The majority of this MRS was excluded from the RI, however, because no disposal operations near the batteries were documented or otherwise known to have occurred, and the former target locations for the gun batteries are in deep water a significant distance off-shore.

1.2.2 RI MRS Delineations

To better define areas where MEC and MC may remain from historical military operations on the Fort Hancock property, ERT reviewed historical reports regarding proving ground operations, including NPS historic resource studies, and discovered a summary report containing a map of the locations of six impact areas associated with the historic proving ground. This key document identifies the location of proof firing targets and indicates that guns were fired from north to south along the beach (NPS undated report). No other testing, training, manufacturing, or disposal areas potentially containing MEC were found in the NPS documents reviewed (NPS 1981, 1982, 1983).

The impact areas are the basis for most of the MRSs investigated during the RI. Buffer zones equal to the radius of the targets were added on all sides of the circular target areas, allowing for under- and over-shoots. A revised boundary was drawn for the Livens area, based on newly-discovered documentation of a 1927 fire in a storage bunker. A report was found verifying that the source of the projectiles was kick-out from the fire or explosion (US Army CWS, 1927). While it is possible that this represents a disposal area because there is no documentation of cleanup activities, intact ordnance is not expected to be present due to the intensity of the fire.

An in-water MRS, parallel to the proving ground and target areas, was established to address areas on the beach where munitions have been found, portions of the former proving ground that may have eroded into the ocean, and off-shore areas to a depth at which recreational users or NPS employees may come into contact with MEC, if present.

The re-configuration of MRSs was discussed during technical project planning (TPP) meetings and presented in the Work Plan, which was reviewed by NJDEP and NPS. The MRSs for the RI are described below and shown in Figure A-1-4. The new MRSs and associated acreages are unofficial and were not reported in FUDSMIS. Because the footprints of the MRSs are expected to shrink as a result of the RI, there is no reason to report these MRS acreages in FUDSMIS; the final RI results will be used to outline the new MRS boundaries and determine final acreages for official reporting.

A cross-walk between the SI MRSs and the RI MRSs is provided in Table 1-2 (at the end of Section 1.0).

- MRS-1, 1,000-Yard Impact Area. 99 acres, covers the northernmost part of the proving ground from the southern border of the impact area to and including the firing points.
    - Includes an area referred to as the B003 Area, a 100x100 foot investigation grid in which MEC was found during the 1998 EE/CA conducted by USACE (discussed in 1.4.4)
- MRS-2, 2,000-Yard Impact Area. 151 acres, covers the area between the 1,000 and 2,000-yard impact areas.
- MRS-3, 2,500-Yard Impact Area. 89 acres, covers the area between the 2,000 and 2,500-yard impact areas.
- MRS-4, 3,000-Yard Impact Area. 73 acres, covers the area between the 2,500 and 3,000-yard impact areas.
- MRS-5, 3-Mile Impact Area. 205 acres (exclusive of MRS 7), covers the area between the 3,000-yard and 3-mile impact areas.
- MRS-6, 3.75-Mile Impact Area. 90 acres, covers the area between the 3 and 3.5-mile impact areas.
- MRS-7, Livens Discovery Area (term coined in 1998 EE/CA). 29 acres, lies mostly within boundary of MRS-5. The center of the MRS is the location of the former storehouse that contained the Livens projectiles and caught fire in 1927. A hazard fragmentation distance for a Livens plus an investigation buffer resulted in a 600-foot radius circle.
- MRS-8, Water MRS. 154 acres along the eastern shore of the property, parallel to the former proving ground and impact locations. The MRS extends eastward into the ocean approximately 100 yards, reflecting a 6-foot depth contour (at mean lower low water). Six feet was used to reflect a conservative maximum depth for human receptors to potentially encounter MEC through fishing, wading or swimming, activities that are regularly conducted at Sandy Hook recreation area.

In addition to the eight MRSs described above, in response to concerns from NJDEP that more former batteries should be included in the RI, two Potential Areas of Interest (PAOIs) were investigated. Also shown in Figure A-1-4, these PAOIs address the 9-Gun Battery area and the Kingman and Mills Battery areas. These PAOIs plus the batteries inside the MRS footprints address 11 of the 20 batteries associated with Fort Hancock.

1.3 Historical Information

During the American Revolution, the peninsula was occupied by British troops. After the colonists gained independence, Sandy Hook was established as a coastal defense position to protect New York Harbor. Before the War of 1812, the government arranged for defensive capability improvements to the site (USACE, 1993).

In 1857, the U.S. Engineers began the construction of a stone fort on Sandy Hook. The fort was sometimes referred to as Fort Hudson or Fort Lincoln, but its official designation was the Fortifications on Sandy Hook, New Jersey. The United States Civil War interrupted the construction and the work was never completed. The site was abandoned in 1866 until 1874.

In 1874, the federal government chose the property for the United States Army's first official proving ground for testing weapons and ordnance. All the experimental guns and carriages manufactured by the Army Gun Factory, other arsenals, or private contractors for the seacoast defenses, were tested at Fort Hancock (USACE, 1993). In 1891, smokeless powder was tested at Fort Hancock and accepted by the Army for use. In 1890 and 1895, the U.S. Engineers improved the area and constructed additional facilities. On 30 October 1895, the facility officially was designated Fort Hancock after Major General Winfield Scott Hancock. In 1901, the original proving ground was moved slightly south of the original location. During its existence in both locations, the Army built several batteries, some of which still exist. During World War I, Fort Hancock served as a training center for troops going overseas. In 1918, the proving ground moved to Aberdeen, Maryland (Aberdeen Proving Ground, APG); however, Fort Hancock remained an important post for anti-aircraft defense. Fort Hancock continued to function in this capacity throughout World War II. In 1950, Fort Hancock was deactivated, only to be reactivated the following year because of the Korean conflict. In 1953, Fort Hancock was deactivated again and called into service in 1954 as a Nike missile site. From 1954 to 1959, the site housed Nike Ajax missiles and from 1958 to 1974, Nike Hercules missiles. In 1956, the Army also established an important radar facility at Fort Hancock (USACE, 1993).

As early as the 1920s, the State of New Jersey investigated the possibility of acquiring some of the land on Sandy Hook for use as a state park. In September 1961, the Army agreed to relinquish 350 acres to the State for this purpose. On 8 January 1962, the State of New Jersey took possession of the 350 acres and 110 additional acres to total 460 acres. The Sandy Hook State Park officially opened on 14 July 1962. In 1964, the State acquired an additional 271 acres from the Army.

In December 1973, the NPS took possession of the park from the State of New Jersey. NPS integrated the Sandy Hook Park into the larger Gateway National Recreation Area, which was created in 1972. On 31 December 1974, the Army deactivated Fort Hancock. Final disposition of Sandy Hook's acreage was directed on 24 January 1978; 1,623.85 acres total became the property of the NPS and the remaining 67.78 acres went to the U.S. Coast Guard. On 17

December 1982, the entire peninsula was declared a National Historical Landmark (USACE, 1993).

Since the NPS acquisition of the site, USACE completed two different beach replenishment dredging operations (1982-83 and 1989) on the southern beaches that brought munitions-related materials to the site. The dredging operations were conducted to improve the beaches. Materials dredged were deposited on the beach in the southeastern portion of the peninsula, at its narrowest location. Munitions items and debris were said by NPS employees to have been found in the piles of dredged sand (USACE, 1993). There is no documentation concerning the specifics of these finds.

1.4 Previous Investigations

Multiple investigations have taken place at Fort Hancock. The following are summaries of those investigations that were useful for this RI investigation.

1.4.1 Inventory Project Report

CENAN prepared an Inventory Project Report (INPR) for Fort Hancock, dated 30 September 1991. Site visits were performed in May, June, and September of 1991 in support of the INPR. The report documents a Proving Ground on the northeast beach where artillery shells were found during searches by Explosive Ordnance Disposal (EOD) personnel since 1974. The INPR included a Findings and Determination of Eligibility that stated that the site comprised 1,691.63 acres fee and 1.14 acres easement, disposed of in 1978. The INPR concluded the site was eligible for the DERP-FUDS program (USACE, 1991). Please note that the 1,691.63 FUDS acreage is lower than that that reflected in the FUDS boundary shown on Figure A-1-1 (1,786 acres, approximately 94 acres more), as there has been significant sand accretion on the northern end of the peninsula since the time of the Government's accounting of the acreage in 1806.

The types of ordnance listed on the risk assessment code (RAC) scoring sheet attached to the INPR included medium/large caliber [20 millimeter (mm) or larger] and practice grenades with spotting charges. Chemical agents/radiological materiel munitions were not identified on the scoring sheet. The overall RAC score for the site was a 2, indicating a relatively severe hazard, based on the presence of munitions in publicly accessible areas (USACE, 1991).

1.4.2 Archive Search Report

USACE prepared an ASR in 1993 for Fort Hancock that described the site's munitions-related history, its physical characteristics, pertinent real estate transactions, and the potential for ordnance and explosive waste (OEW). (Note that "OEW" or "ordnance" was used in the ASR to describe munitions-related items, and the report did not distinguish between items that contain an explosive hazard (MEC) and items that are inert MD). From interviews and a site tour conducted with NPS personnel as a part of the ASR site visit, the report relates NPS encounters with munitions-related items. Numerous types of items had been found over the years of the two primary interviewee's tenures, including projectiles, hand grenades, and 3-, 6-, and 12-inch artillery rounds. EOD units had been called in on some of the finds, and others were determined by the NPS employee who responded to munitions finds to be inert and were kept as artifacts. This employee also stated that finds were much less frequent than they were 15 years prior, and items were more concentrated in the former proving ground (RI MRS-1) than other parts of the property. Another interviewee familiar with ordnance finds stressed the pattern and danger of finding ordnance from erosion, weathering, and movement of the beaches by sea currents and wave action; the NPS staff also noted that some items found on the beaches (three 12-inch rounds in particular) may have originated from the USS Turner, a ship that exploded not far off-shore in 1944. A Navy EOD unit also found artillery rounds, possibly from the Turner incident, in 1980, in the waters surrounding Sandy Hook (USACE, 1993). The following paragraphs summarize more of the ASR findings.

In 1979, the Sandy Hook Unit was closed for a period of one month due to the discovery of 18 munitions items on the property. From 1975 to 1984, two NPS personnel kept a hand-written log of items found across the site, cataloging 55 occasions on which munitions items were found. In 1993, near the time of the ASR site visit, three field artillery rounds were found by NPS archaeologists who were working to uncover the foundation of the original proving ground, in preparation for a construction project. Two of the items were radiographed and removed and one was blown in place by an EOD unit (USACE, 1993).

In 1981, NPS personnel discovered four Livens projectiles in an overgrown area in the central portion of the peninsula, northeast of the Nike missile silos. An Army TE Unit from APG recovered the projectiles, which contained an unknown liquid filler speculated at the time to be either phosgene or mustard agent, which are classified as CWM. The area where the items were found had historically contained railroad sidings and storage bunkers related to ordnance depot operations. Within approximately 200 feet of the location where the projectiles were found, the vegetation was cut back and the area was inspected by NPS and Army personnel, who found no other munitions items. The projectiles were thought to be residual material from an explosion that occurred in one of the bunkers. All four Livens projectiles were found intact in the storage configuration (no fuze, shipping plug installed). TE personnel packaged the projectiles and transported them to APG. TE staff were requested to contact NPS to confirm which agent was inside the projectiles; however, TE staff never followed up with NPS (USACE, 1993). See Section 1.2.1 for information on the final analysis of the filler material and determination contain CWM.

On the subject of CWM, the ASR further states that phosgene gas was stored at Fort Hancock (USACE, 1993). Subsequent review of the archival documents referenced in the ASR revealed that the gas was in cylinders (not weaponized and not considered CWM) and was stored temporarily while funds for transport back to Aberdeen Proving Ground were secured (CWS, 1921). The ASR also states that in 1938, a Chemical Warfare Reserve Officer inadvertently discharged a 4-inch, titanium tetrachloride (FM smoke)-filled artillery shell while holding it (USACE, 1993). [Note: The discussion of CWM in the ASR and archival documents demonstrate how fillers other than high explosives were at one time labeled chemical filler and consequently called CWM by the Chemical Warfare Services Branch.]

The interviewees stated that various types of ordnance were found in sand that was dredged onto the southernmost portion of the peninsula to replenish an area washed away during a storm in 1982. USACE Civil Works Programs conducted the beach replenishment using pipe lines to replace a large portion of land, and ordnance was found in the replenished area sometime thereafter (date and specifics of finds not provided). It was speculated that the source of the ordnance dredged onto the beach was the USS Turner. (Note that NPS employees have subsequently pointed out that the replenished areas have long since eroded and have been rebuilt by natural processes several times since.)

The ASR also references ordnance found as a result of dredging in 1989, when three 12-inch rounds were apparently found on the northwestern shore of the peninsula (on what is now U.S. Coast Guard property) when the Navy decided to extend its pier facilities on Sandy Hook. The items were found before dredging occurred; no description of the location of the find was provided, but the interviewees said the Navy had an "ammunition holding area" in the vicinity of the pier. USACE recently followed up with the U.S. Coast Guard, which now uses and maintains the piers, to determine if there may be an underwater MEC disposal area in this area. The staff in charge of overseeing dredging in the 1990s and in 2007 stated that no ordnance items have been found in recent dredging events (USACE, 2011). Because there is no documentation of a disposal area, no MRS was established near the piers.

Other items of potential environmental concern mentioned during the ASR interviews include the following discoveries, which were not substantiated and therefore not included in the RI:

- The discovery of wooden barrels near Spermaceti Cove in an area where the Army stored nitroglycerin. During a follow-up conversation, NPS employees explained that beach erosion exposed three large barrels in 1977 and a site map had identified this area as storage for fulminate of mercury. However, the barrels were found to be empty except for debris such as coal, spikes, old nails, and rocks (USACE, 2009a).
- Plum Island, where hand grenades had been found and removed. As stated in 1.2.1, the employee said during the ASR interview that hand grenade training took place on the property; he subsequently stated that this assumption was probably incorrect.) Other employees have suggested that the area is too close to the civilian areas of Highlands to have been a grenade court). During subsequent USACE investigations (EE/CA and SI), no munitions-related items were found on the island.
- "Thousands" of fragmentation hand grenades were dumped in the waters off the north end of the peninsula. As stated in Section 1.2.1, the interviewee could not verify this statement or provide a location for the alleged northern disposal area (MRS 3 in the SI).
- A former small arms range where small arms cartridges are periodically found (location was only verbally described, on the southern portion of the site on the beach, but no site figures have been located; as described, the area was encompassed by RI MRS-6).
- The Navy conducted an ordnance sweep off the coast (timeframe and location unidentified) and found French mortar rounds.

1.4.3 Interim Removal Action

In 1994, USACE conducted an interim removal action (IRA) in nine small areas of Fort Hancock that were slated for various construction or improvement projects by NPS. The IRA involved a geophysical surface and subsurface survey during which 136 grids were established and 4,649 anomalies were investigated (out of 10,162 detected). These 136 grids were in the general area of the current MRS-1 and northern end of MRS-2. Of the investigated anomalies, 64 contained a wide variety of munitions items, which were subsequently removed. The report identified only two of the items as high explosive (HE) rounds, one being a 6-inch armor piercing projectile found in the old north beach parking lot I and the other being a 12-inch armor piercing round found in north beach parking lot J (USACE, 1994). The IRA report indicates both the 12-inch round and the 6-inch round were destroyed.

1.4.4 Engineering Evaluation/Cost Analysis

In 1998, USACE undertook an Engineering Evaluation/Cost Analysis (EE/CA) to more thoroughly investigate ordnance on Sandy Hook (USACE, 1999). Ten areas of concern were established for investigation, based on the ASR and an analysis of historical aerial photographs conducted by the U.S. Army Topographic Engineering Center. The 10 areas were lettered A through J and are outlined as shown in Figure A-1-2. (Note that Areas A, C, D, H, and J were not identified in the ASR, nor were there full descriptions of either underground storage magazines [a reference to the storage bunker that exploded in the Livens area] or foreign ordnance [a brief mention of French mortars found by the Navy off-shore]. Only three of these areas were located on a map in the ASR, and they only roughly correspond to areas B, D, and I. It is apparent from these comparisons that the EE/CA areas of concern were based on additional information which was likely provided by NPS staff.

A total of 3,904 anomalies were identified during the geophysical investigation; of these, 1,710 were intrusively investigated. A total of 107 anomalies (6% of total) were MEC or MD, including projectiles, fuzes, grenades, and metal fragmentation from exploded ordnance. Twenty-six (26) intact conventional projectiles, ranging in size from 75mm to 12-inch, as well as one intact Livens projectile, were found during intrusive activities. The three primary discovery areas were (1) the northwest portion of Area E, the Livens Discovery Area, (2) the southeast end of Area B (Former Proving Ground), with both live and inert items found in the surf zone and presumed to have been eroded from the dunes and transported and deposited by ocean currents and tides from a near-shore source area, and (3) an area in the north end of Area B near the original proof battery, centered around Grid B003. Grid B003 contained 89 anomalies, 13 of which were excavated. Sixteen intact projectiles were discovered in seven of the 13 anomalies investigated. However, none of the 16 projectiles contained HE, although two were fuzed.

A total of five conventional MEC items found during the EE/CA were confirmed to contain explosive charges, including one 5-inch Shrapnel round and one 7-inch projectile containing HE (southeast end of Area B on beach in surf zone), one live Mark V fuze (north end of Area B), and two 75mm projectiles (fuzed but no HE at the north end of Area B, Grid B003). MEC and MD also were found at the Livens Discovery Area, including one intact Livens projectile. Radiographic testing in the field indicated that the projectile did not contain a burster and that the filler was likely FM smoke. These tests were confirmed at a later point in time (USACE, 1999).

An explosive risk assessment was conducted as part of the EE/CA, using the Ordnance and Explosives Cost-Effectiveness Risk Tool (OECert), resulting in the recommendation for clearance to depth in two small areas and site-wide institutional controls (e.g., warning signs, routine reconnaissance inspections, etc.). The first area recommended for clearance was proximal to Grid B003 due to the high concentration of munitions items found in this area. The second area was Grid E004 (the Livens Discovery Area) and vicinity, to include Grid E004 and extending to Grid E001 to the north, Grid E008 to the south, Hartshorne Road to the west, and the wetlands to the east. Although the removal actions were never undertaken, NPS maintained their protocol for public education through information sheets/signage. (Supplemental Archive Search Report, 2004)

As part of an Army-wide range survey effort undertaken in 1999, USACE compiled an inventory of all areas potentially containing MEC (aka MRSs), based on existing information, and documented the required data elements in supplemental ASRs. The range survey assigned acreages for all such areas and included entire range fans, as well as potential disposal areas. For Fort Hancock, the ASR Supplement was based solely on information in the ASR and the still-present gun batteries, and inference was drawn from the ASR text to draw polygons around the areas and assign acreages. The six MRSs identified in the ASR Supplement are described in Section 1.2.1. The Northern Battery Complex represents the overlapping range fans emanating from 13 of the batteries that extend into the surrounding waters to the maximum range of the largest munitions potentially fired. The MRS acreages for the gun batteries are based on standard range configuration (including surface danger zones) for the munitions potentially fired. The ASR Supplement summarized the munitions types, dates of use, and RAC score for each MRS (USACE, 2004).

RAC scoring was completed to evaluate hazard severity and hazard probability. The scoring was based on the information in the ASR and known reports of EOD actions. Explosive projectiles 20 mm or greater in size are identified on the RAC scoring sheets. All ranges and batteries at Fort Hancock had a RAC score of 1 with the exclusion of the Small Arms Range, which had a RAC score of 5. A RAC score of 1 indicates a hazard severity that is either catastrophic or critical combined with a probability level of either frequent or probable. A RAC score of 5 indicates that there is no hazard severity (USACE, 2004).

1.4.5 <u>Site Inspection</u>

In 2007, USACE completed an SI as part of a DoD-wide effort to evaluate the inventoried MRSs for further action. The purpose of a SI is to determine whether a detailed investigation (RI/FS) is needed or if the site warrants no further remedial action. A secondary purpose of the SI was to obtain information necessary to evaluate the MRSs using DoD's Munitions Response Site Prioritization Protocol (MRSPP), a tool used to rank sites for further action. The SI served to inspect each of the six MRSs identified in the ASR supplement for MEC on the surface and to collect environmental samples to determine if there may have been a release of MC. The SI did not factor in the areas of concern identified in the EE/CA, nor did it involve additional historical research. Figure A-1-3 shows the SI MRS designations as well as locations sampled during the SI.

No surface MEC were observed during the SI (no intrusive work was done for the SI). A total of 59 surface soil samples (including 3 background samples), 1 surface water sample, and 2 sediment samples were collected. Surface soil risk screening showed slightly elevated concentrations of metals at the B003 Grid Area. Surface soil and sediment screening (ecological criteria) showed slightly elevated concentrations for some metals at Nike Pond. Surface water risk screening showed slightly elevated arsenic (human health criteria), and slightly elevated arsenic, lead, and titanium (ecological criteria). The SI recommended an RI/FS for both MEC and MC for most of the MRSs.

In response to comments from NJDEP on the Final SI report, USACE conducted two follow-up activities. First, it conducted a formal safety briefing with NPS representatives to ensure they are aware of the potential dangers involved in MEC items that may exist at the property. Second, as summarized in Section 1.4.2 of this report, USACE verified that no CWM has been found on the property to date, and determined from a probability assessment that it is not suspected to be present.

Table 1-2. Crosswalk of EE/CA Areas of Concern, and SI and RI MRS Designations

RI MRS	FUDSMIS MRS	Notes
MRS-1 1,000-Yard Impact Area (99 acres)	MRS 5 Northern Battery Complex (portion) – (total 356 acres)	RI MRS-1 is the northern portion of the proving ground, covering both the "old" and "new" proof battery firing points, down to the 1,000-yard target (impact) area as well as estimated buffer areas. It encompasses the EE/CA Grid B003 Area as well as an area to the east where historical aerial photographs show ground disturbance (a potential sign of munitions impact craters). The park's northern parking lot and beach plaza (shower house) are included in this area, as well as portions of North and Gunnison Beaches. SI MRS 5 partially overlaps RI MRS-1 and covers a small portion of the historic proving ground. As discussed in Sections 1.2.1 and 1.4.5, the "Northern Battery Complex" mostly consists of the large, overlapping range fans emanating from 13 of the firing batteries to presumed off-shore target locations at the maximum distance the guns could fire. The majority of this acreage was excluded from the RI, as (1) limited firing of the guns is likely to have occurred, since they were installed between 1890 and 1933, during which time harbor defense was not necessary when the guns were in place, (2) no disposal operations are documented to have occurred near the batteries, (3) there are limited reports of munitions finds on the northern beaches, (4) much of the northern tip of the peninsula is sand that has accreted since firing operations ceased, likely burying any munitions that may have been in near-shore or on-shore areas, and (5) the off-shore targets would have been in deep water thousands of feet from shore.
MRS-2 2,000-Yard Impact Area (151 acres)	MRS 5 Northern Battery Complex (portion) – (total 356 acres)	MRS-2 encompasses the second target area, moving from north to south from the proving ground firing area. A small portion of SI MRS 5 is covered by this area.

Table 1-2. Crosswalk of EE/CA Areas of Concern, and SI and RI MRS Designations

RI MRS	FUDSMIS MRS	Notes
MRS-3 2,500-Yard Impact Area (89 acres)	MRS 5 Northern Battery Complex (portion) (total 356 acres)	MRS-3 encompasses the third target area, moving from north to south from the proving ground firing area. A small portion of SI MRS 5 is covered by this area.
MRS-4 3,000-Yard Impact Area (73 acres)	NA	MRS-4 encompasses the fourth target area, moving from north to south from the proving ground firing area. The SI covered no portion of this MRS.
MRS-5 3-Mile Impact Area (205 acres)	NA	MRS-5 encompasses the fifth target area, moving from north to south from the proving ground firing area. The SI covered no portion of this MRS.
MRS-6 3.75-Mile Impact Area (90 acres)	MRS 1 Southern Dredging Disposal Area (31 acres)	MRS-6 encompasses the sixth target area, moving from north to south from the proving ground firing area. This MRS covers the SI MRS 1 in its entirety, the area where beach replenishment occurred, as well as the former small arms range.
MRS-7 Livens Discovery Area (29 acres)	MRS 2 Livens Projectile Disposal Area (24 acres)	MRS-7 covers the area where the 1927 storehouse explosion took place and spread Livens projectiles into an area not discovered until 1981. To draw the MRS boundary, a blast radius for the Livens projectiles, plus a buffer area, was measured from the storehouse location. The Livens found in 1981 contained FM smoke. In the SI report and ASR Supplement, the location of the Livens area was incorrectly identified (too far to the north). Although this area was called an underground storage magazine in the 1998 EE/CA report, there is no documentation or visual evidence to date that the magazines in the ordnance depot were underground.

Table 1-2. Crosswalk of EE/CA Areas of Concern, and SI and RI MRS Designations		
RI MRS	**FUDSMIS MRS**	**Notes**
MRS-8 Water MRS (154 acres)	MRS 5 Northern Battery Complex (offshore portion) – (total 130,580 acres)	154 acres along the eastern shore of the property, parallel to the former proving ground and impact locations. The MRS extends eastward into the ocean approximately 100 yards, reflecting a 6-foot depth contour (at mean lower low water). Six feet was used to reflect a conservative maximum depth for human receptors to potentially encounter MEC through fishing, wading or swimming activities.
NA	MRS 3 Northern Disposal Area (1 acre)	This was presumed to be the area off the north end of the peninsula, as described in an ASR interview, where fragmentation grenades were dumped. However, there is no map or description to document the dump or its location. The interview subsequently stated that items may possibly have washed up on-shore in this area, but the location of the dump is entirely unknown. The interviewee subsequently did not recall this area and stated that he may have been referring to items that washed up on shore in the general vicinity.
NA	MRS 4 CWM Research and Development Laboratory (0.06 acres)	No CWM is documented to have been used or developed at Fort Hancock, and the name of this building in the ASR is a misnomer. The correct name was "School/Chemical Laboratory." The building was used for chemistry tests associated with conventional ordnance fired at the proving ground.
NA	MRS 6 Plum Island/Hand Grenade Court (0 acres-unlocated)	The ASR provides no documentation of the location of a grenade court, only a statement by an NPS employee that grenade training took place. The interviewee subsequently explained that the presence of a training range was conjecture and is not thought to be accurate. The found item was thought to have washed up from an off-shore area. (Note that none of the anomalies found on the island during the EE/CA were MEC-related.)

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2.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

2.1 Overall Site Description:

2.1.1 Surface Features

Sandy Hook is a coastal spit, or peninsula, that projects northward, more than 5 miles into the Atlantic Ocean. Beach and dune sands make up all of the Sandy Hook spit. All of the MRSs have similar surface features, with relatively flat beach areas on the eastern side and densely vegetated areas on the western side. MRS-1 is 99 acres comprising roughly equal areas of beach and densely vegetated inlands. The North Beach bath house and associated large parking lot lie within MRS-1. MRS-2 is 151 acres in size and contains within its boundary the sewage treatment plant, a maintenance yard, and a portion of Atlantic Drive. Much of the acreage west of Atlantic Drive is NPS excluded areas. Most of the 89 acres of MRS-3 are vegetated with approximately 25 percent beach acreage. A portion of Atlantic Drive lies within MRS-3. MRS-4 is 73 acres, primarily vegetated, with approximately one-third of the acreage being NPS excluded areas.

MRS-5 is 205 acres in size and contains the former Nike Missile site, two bunkers, Fishing Beach road, the multi-use path, the Nike Pond, a bath house, and a parking lot. The eastern edge is a long strip of beach area with the remainder densely vegetated; roughly 40% of the acreage is NPS excluded areas. MRS-6 is 90 acres in size and contains the visitor’s center, multi-use path, a bath house, and parking lot. This MRS is predominantly beach; all of the area west of Hartshorne Drive is NPS excluded acreage. MRS-7 lies within the MRS-5 footprint. It is densely vegetated acreage with almost all of it being NPS excluded areas.

2.1.2 Meteorology

Monmouth County’s climate generally is moderate, with warm summers, mild winters, and evenly distributed average monthly rainfall. Coastal areas, like Sandy Hook, have somewhat cooler summers and milder winters, with less snowfall than inland areas. February is usually the month with minimum precipitation (2.89 inches (in.) average at Sandy Hook) and June is normally the month of maximum rainfall (4.45 in. average). Precipitation data have been collected at Sandy Hook from 1969-92 and averaged 46.03 in. annually during that period, or about 3.84 in. per month. Of the total amount, 25.5 in. of snowfall (2-3 in. of water equivalent) are included (USACE, 2007).

Summer temperatures are warm, but seldom extreme due to the effect of the Atlantic sea breezes. Highest monthly temperatures occur in July (74-75 degrees Fahrenheit (°F) average). The lowest monthly average temperature occurs in January (33-34 °F). With the ocean influence, winds may blow across Sandy Hook from any direction; however, wind data are not recorded on Sandy Hook. The nearest wind records are maintained at John F. Kennedy (JFK) International Airport on Long Island, New York, about 15 miles northeast of the site. JFK records indicate that the predominant wind direction is from the west, and varies from the southwest to the northwest. Average velocities are 10-12 miles per hour (mph) from May through October and increase to 12-14 mph from November through April. The direction of the majority of the peak wind gusts have been from the quadrant ranging from the west through the northeast (USACE, 2007).

2.1.3 Surface Water Hydrology

There are no significant surface streams on the peninsula, and only a few marshy areas noted on the topographic maps. Except during intense rainfall events, infiltration is high and surface runoff minimal due to the sandy soils. Therefore, surface water changes are mainly due to tidal action, including daily fluctuations and storm surges. Mean tide ranges from approximately -1.6 feet to 3 feet National Geodetic Vertical Datum (NGVD), while spring tides range from -2.1 feet to 3.5 feet NGVD. Flooding occurs only as a result of storm surges or hurricanes. The Federal Emergency Management Agency has not created a flood insurance rate map for the peninsula, but the closest mainland areas, Highlands and Sea Bright, have been mapped as being within the 100 year flood zone.

Surface water does not supply drinking water on or around Fort Hancock given the proximity to the ocean; all surface water is non-potable.

There are three ponds on Sandy Hook: North Pond, Round Pond, and Nike Pond (Figure A-1-1). The only pond located within an MRS (MRS-5) is Nike Pond. Originally a natural pond, the U.S. Army altered it during World War II for use in testing small, amphibious jeeps. Instead of a natural shoreline with a gradual slope into the water, the pond is edged with concrete that acts as a retaining wall. While recreational fishing occurs along the beaches at Sandy Hook, it does not occur at any of the ponds (USACE, 2007).

2.1.4 Geology

Fort Hancock is situated on the New Jersey Coastal Plain, a seaward-dipping wedge of unconsolidated sediments ranging in age from Cretaceous to Recent. These sediments are clay, silt, sand, and gravel, and represent continental, coastal, or marine deposition. The Cretaceous and Tertiary sediments typically dip gently to the southeast at about 25 feet (ft)/mile. Overlying deposits of Quaternary age, where present, essentially are flat lying. The Coastal Plain deposits thicken seaward at the Fall Line to more than 6,500 ft at the southern tip of Cape May County (USACE, 1993). The New Jersey Coastal Plain is underlain by unconsolidated rock of Mesozoic and Cenozoic age. These strata occupy a belt extending from Raritan Bay southward along the Atlantic and Gulf Coasts into Mexico.

Sandy Hook is a coastal spit that projects northward, more than 5 miles into the bay. The spit is a continuation of a narrow offshore bar. Sandy Hook is an example of an active compound recurved spit (i.e., the end of the sand bar turns landward), which has lengthened about 1,000 ft in the past quarter century. Quaternary clay deposits have been discovered beneath Sandy Hook spit beach sands. Dunal topography is present on parts of the spit. Some of the recent growth of the spit is at the expense of the spit elsewhere. Groins, along the northern part of the spit, and a large seawall along the barrier bar and southern part of the spit, have been constructed to curtail the loss of sand from the open ocean side of Sandy Hook.

2.1.5 Soils

Beach and dune sands make up all of the Sandy Hook Unit spit. The beach sand is composed principally of quartz from underlying and nearby formations; however, glauconite grains mainly reworked from the nearby older formations, can form several percent of the beach sand. The glauconite grains impart a dark-green to dark-gray speckled appearance to the sand. Grain size ranges from clay to small pebbles, but the sand is mainly medium to coarse. The sand is fairly clean and loose and shifts about readily. The dune sand is chiefly medium grained and better sorted than the beach sand. The dunes are partly stabilized and fairly well covered by bushes and grass. The thickness of the deposits ranges from about 20 ft immediately offshore of the mouth of Navesink River to more than 200 feet at the northern tip of the spit. These Quaternary deposits also contain a discontinuous unit of marine foramineferal clay.

The surficial soils at Fort Hancock consist mainly of beach and dune sands. A small area on the western side of the spit contains tidal marsh deposits. The sand deposits are composed of yellowish- to greenish-gray, fine to very coarse quartz sand. Shell fragments are abundant. These deposits typically are loose (USACE, 2007).

2.1.6 Hydrogeology

Two major aquifer systems are associated with Fort Hancock and the surrounding peninsula. Groundwater is primarily found in the Northern Atlantic Coastal Plain aquifer system, with a typical yield of 250 to 300 gallons per minute of groundwater in high-capacity wells. Groundwater beneath the northern portion of the peninsula is associated with the Englishtown aquifer. These features, and the coastal topography of the site, will affect the general flow of groundwater.

Drinking water for the entire Sandy Hook peninsula is supplied by one well approximately 880 feet deep into a confined aquifer, and surrounding boroughs receive drinking water from other public community supply wells. Figure A-1-1 shows the nearest public drinking water wells, residences, and other key features in the vicinity of Fort Hancock (USACE, 2007).

2.1.7 Demography and Land Use

The Sandy Hook peninsula currently is part of the Gateway National Recreation Area and is used for a variety of purposes year-round. Public attractions include access to a 5-mile multi-use pathway, the Sandy Hook Visitor Center, the Fort Hancock Museum, the Sandy Hook Light House, and the Sandy Hook Bird Observatory (Figure A-1-4). NPS Ranger-led programs, self-led programs, cooperative educational programs, and teacher workshops are available on Sandy Hook. Recreational activities include hiking, wind surfing, swimming, and beach fishing (NPS, 2006). There are full-time and seasonal residents on Sandy Hook as well as an office of the National Oceanographic and Atmospheric Administration (NOAA), the Marine Academy of Science and Technology (a high school operated by the Monmouth County Vocational School District), field offices of other non-profit environmental advocacy groups and a child care center. Many of the former Fort Hancock military buildings still exist, including housing, batteries, and silos. NPS has stated that Sandy Hook will remain part of the Gateway National Recreation Area in the future and that no changes to the current land use are projected.

Sandy Hook has many visitors, NPS employees, U.S. Coast Guard employees, and U.S. Coast Guard Family Housing. Many of the Coast Guard family members reside in homes on the 68 acre Coast Guard property. There are 67 housing units with an average of three people per unit on the U.S. Coast Guard property totaling approximately 200 residents (Nelson, 2006). Approximately 100 service people/employees are present on the U.S. Coast Guard Property on a typical day (Nelson, 2006). Additionally, NPS leases many buildings on the peninsula to a variety of agencies and groups. There are approximately 15 residents in several buildings (duplexes and one single housing unit) on NPS property that are inhabited as permanent or semipermanent residences (Fallon, 2006). The NPS employs 55 permanent staff and 94 temporary (summer) employees (NPS, 2006).

The New Jersey Marine Sciences Consortium (NJMSC) annually serves approximately 20,000 school children and 500 educators through its successful K-12 education programs, all conducted in its coastal classroom along the beaches, bay shores, and marshes of Sandy Hook. NJMSC is located on Sandy Hook at 305 Gunnison Rd (NJMSC, 2010). The Sandy Hook Child Care Center serves a maximum of 15 children per day. The child care center is located on Sandy Hook at 335 Pennington Rd (Sandy Hook Child Care Center, 2010).

The U.S. Coast Guard Station presently is in use on Sandy Hook on the north end of the site with a functioning, on-line weather station. The mission of the U.S. Coast Guard includes search and rescue, national homeland security, law enforcement, and recreational boating safety. This mission is not expected to change.

2.1.8 Ecology

The Sandy Hook peninsula is characterized by a wide variety of habitats including forest, wetland, dune shrubland, dune grassland, beach, and adjacent benthic habitats (NPS, 2008a; NPS, 2008b). Most of the peninsula was identified by NJDEP as a Natural Heritage Priority Site, which contains essential habitat for sensitive species (Alion, 2007). The peninsula serves as a valuable migratory flyway, stopover site, breeding site, and wintering site for many bird species of concern (NAS, 2010). Threatened, endangered, and special concern species within or near Fort Hancock are primarily associated with beach and dune habitats and include three herbaceous plants, two insects, several birds, four reptiles and amphibians, and one fish (USFWS, 2008; USFWS, 2009a; NJDEP, 2010a; NJDEP, 2010b). All RI field activities complied with NPS, USFWS, and NJDEP guidance for protecting species and habitats of concern. Figure A-2-1 presents the ecologically sensitive areas across the site.

Sensitive ecological communities at Fort Hancock include a globally-rare 231-acre Maritime Holly forest, which overlaps with the western edge of the MRSs and is not open to the public (NPS, 2008a; NPS, 2008b; NPS, 2010a). Because of the sensitive ecological communities, NPS imposed vegetation removal or cutting restrictions on specific ‘excluded areas’. Vegetation was not cut within the Maritime Holly forest, and disturbance to this excluded area was further minimized by limiting geophysical data collection to existing trails. Other sensitive plants of concern in the MRSs were not cut to minimize disturbance, including Beach Wormwood (*Artemisia campestris caudata*), American Holly (*Ilex opaca*), Eastern Red Cedar (*Juniperus virginiana*), Northern Bayberry (*Myrica pensylvanica*), Beach Plum (*Prunus maritima*), Common Hackberry (*Celtis occidentalis*), Serviceberry (*Amelanchier arborea*), and experimental vegetation research plots consisting of Asiatic Sand Sedge (*Carex kobomugi*) and American Beachgrass (*Ammophila breviligulata*).

The federally-threatened and state-endangered Seabeach Amaranth (*Amaranthus pumilis*) was not encountered during RI activities. No intrusive investigations occurred within or in the immediate vicinity of the recorded beach habitat of this plant, based on all locations observed by NPS in 2010 (which were limited to MRS-6). Other state-endangered herbaceous plants previously documented at the site (USACE, 1999) were not observed during RI activities, including Sea-beach Knotweed (*Polygonum glacum*) and Coast Flat Sedge (*Cyperus* *polystachyos*). The American Holly, Eastern Red Cedar, Northern Bayberry, and Seabeach Amaranth are shown in Exhibits 1 through 4.

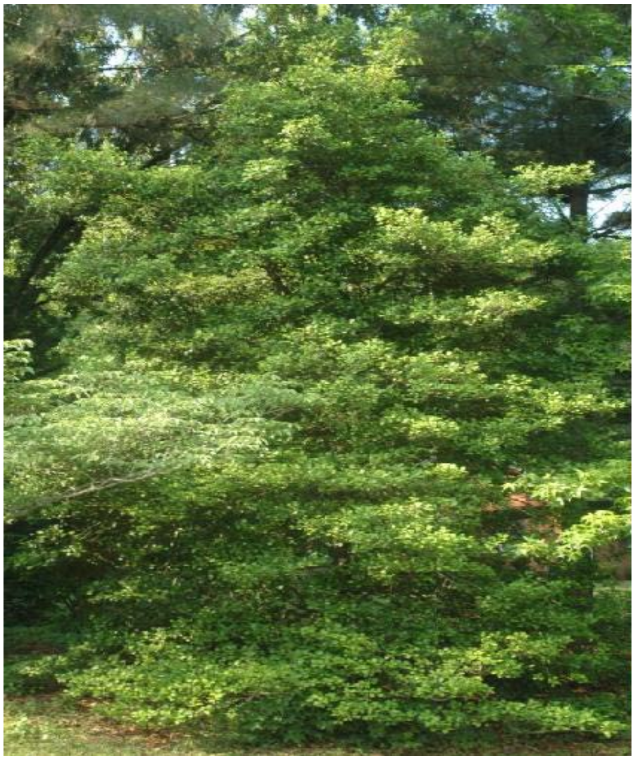

Exhibit 1: American Holly (*Ilex opaca*)

Exhibit 2: Eastern Red Cedar (*Juniperus virginiana*)

Exhibit 3: Northern Bayberry (*Morella pensylvanica*)

Exhibit 4: Seabeach Amaranth (*Amaranthus pumilus*)

Photo sources: ForestryImages.com (USDA and University of Georgia), Duke University, WikimediaCommons.org

Overall environmental impacts within the MRSs were minimized by limiting the geophysical transect width and spacing, limiting the extent of cut vegetation, and preserving undisturbed buffer zones. NPS biologists accompanied field teams when possible to ensure that plant species of concern were properly identified and avoided. Field protocols minimized risks of spreading invasive species such as Common Reed (*Phragmites australis*) and Tree of Heaven (*Ailanthus altissima*). No adverse effects to vegetation or the surrounding media occurred during collection of environmental samples (soil, groundwater, and sediment). No restoration or replanting activities were required, as all holes were properly backfilled and brush cut vegetation was allowed to re-establish naturally.

Wetlands on the peninsula are primarily situated outside of the MRSs. Many of the marine, estuarine, freshwater, and forested wetlands are included in the National Wetlands Inventory (USFWS, 2011) and continue to be delineated by NPS. Small wetland areas were encountered within MRS-1, but were not impacted by RI activities.

Few wildlife species were encountered during RI activities due to the investigation time frame, which was primarily limited to fall/winter/spring months. Harbor Seals (*Phoca vitulina*) were observed on beaches during the field work planning phase, prior to RI activities. Sensitive marine wildlife, such as the federally-endangered and state-endangered Shortnose Sturgeon (*Acipenser brevirostrum*), were not observed.

The federally-threatened and state-endangered Piping Plover (*Charadrius melodus*) nests on Sandy Hook beaches and dunes above the high tide line from approximately March 15 through August 31, although earlier arrivals and later departures have been documented, and public access to nesting areas is not permitted during this time frame (USFWS, 2009b; NPS, 2010). Other sensitive beach-nesting birds at Sandy Hook include the state-endangered Least Tern (*Sterna antillarum*), the state-endangered Black Skimmer (*Rynchops niger*), the federally-endangered and state-endangered Roseate Tern (*Sterna dougallii*), and two species of special state or regional concern: American Oystercatcher (*Haematopus palliatus*) and Common Tern (*Sterna hirundo*). The state-threatened Osprey (*Pandion haliaetus*) nests on tall single-post platforms specifically designed for them in numerous locations on the Sandy Hook peninsula, including within the investigation area, from approximately April through September.

A shorebird monitoring protocol was developed to minimize disturbance to sensitive beach-nesting birds within anticipated (historically fenced) and newly-established nesting areas. Daily coordination between ERT and the NPS-qualified shorebird monitor ensured that no disturbances occurred during field activities within or near plover habitats (including beach and adjacent dunes). All beach efforts within or in close proximity to plover nesting areas were completed by March 18, 2011. Similarly, inland field activities near Osprey nest platforms were coordinated with NPS to prevent disturbance, as these raptors use all existing platforms annually. Although most Osprey nests are located outside of the MRSs, a small number of grids were investigated in the vicinity of Osprey nest platforms. To the extent practicable, demolition of MEC/MPPEH was conducted in a designated area over 1,000 feet from the closest Piping Plover nesting habitat, with additional consideration of Osprey nest platforms and other sensitive species. In mid-September 2011, NPS provided confirmation that all Piping Plovers had departed the peninsula for migration.

The federally-threatened and state-endangered Northeastern Beach Tiger Beetle (*Cicindela dorsalis dorsalis*) is potentially present at Sandy Hook (Knisley, et al., 2005; USFWS, 2009b;

USFWS, 2009c). Disturbance to beach habitat during RI activities was minimized to ensure that this species was not adversely affected, and larval beetles overwintering in burrows were not encountered during intrusive investigations. Within the Water MRS, any adverse effects to benthic and essential fish habitat were minor and temporary.

Any recovered archaeological artifacts deemed to be archaeologically significant were fully documented by USACE and NPS archaeological professionals. Several items, classified as MD were given to NPS at the discretion of the USACE Ordnance and Explosives Safety Specialist (OESS), with the exception of any MEC items that were considered live or unsafe, which required on site detonation.

Field procedures for avoiding, minimizing, and mitigating potential impacts to environmental and cultural resources near the investigation area were developed in consultation with the NPS at Sandy Hook, the USFWS New Jersey Field Office, the NJDEP Division of Fish and Wildlife, and USACE. All procedures were documented in the Environmental and Cultural Resources Protection Plan (ECRPP) section of the Fort Hancock Remedial Investigation Work Plan (ERT, 2010) and the letter addendum to the ECRPP (ERT, 2011). Formal agency consultations and ongoing communication with stakeholders ensured that RI field activities did not jeopardize any federally-listed and/or state-listed species or critical habitats in the investigation area. USFWS concurred that no effects were anticipated for Northeastern Beach Tiger Beetle and Seabeach Amaranth, and determined that potential disturbance to Piping Plover and Roseate Tern would be low and unlikely to cause adverse effects. NJDEP stated that potential adverse impacts to state-listed species were adequately addressed, and NOAA stated that adverse effects to essential fish habitat (EFH) would be minor and temporary.

The NPS has completed a Draft General Management Plan Environmental Impact Statement (July 2013) that describes the no-action alternative and two action alternatives for future management of Gateway, the environment that would be affected by the alternative management actions, and the environmental consequences of implementing the alternatives. This document, in draft form, has been appended to this RI (Appendix I) by agreement with NPS.

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3.0 REMEDIAL INVESTIGATION OBJECTIVES AND PRELIMINARY CONCEPTUAL SITE MODEL

3.1 RI Objectives and Conceptual Site Model

The objective of this RI is to adequately characterize the nature and extent of any potential MC contamination or MEC hazards resulting from the past U.S. military use of Fort Hancock. In order to complete an RI that achieves these objectives, a preliminary Conceptual Site Model (CSM) was developed in the Work Plan (ERT, 2010). A CSM is used to communicate and describe the current state of knowledge and assumptions about risks at a project site. The CSM presents the exposure pathway analysis by integrating information on the MEC and MC source, receptors, and receptor/MEC interaction.

The preliminary CSM is based on the site history of Fort Hancock, where the Old Proving Battery firing point fired to the 3-mile and 3.75-mile impact areas, while the New Proving Battery firing point fired to the 1,000-yard, 2,000-yard, 2,500-yard, and 3,000-yard impact areas (Ordnance History – Fort Hancock [1874-1919]). Primarily using the impact areas and working back toward the firing points, the range fans areas were developed into the six MRS boundaries (MRS-1 through MRS-6) as shown in Figure A-1-4.

MRS-7 and MRS-8 have slightly different CSMs. MRS-7 is the Livens Discovery Area, where the 1927 bunker/storehouse explosion would likely have resulted in "kickouts" (munitions spread beyond the immediate vicinity by the detonation). While no intact munitions are expected to be present because of the intensity of the fire, it is possible that MRS-7 is a disposal area because there is no record of any cleanup that occurred after the 1927 explosion. MRS-8, parallel to the proving ground and target areas, was established to address areas on the beach where munitions have been found, portions of the former proving ground that may have eroded into the ocean, and off-shore areas to a depth at which recreational users may come into contact with MEC, if present.

The source of explosive hazards is primarily UXO resulting from firing activities at the proving ground batteries towards the six impact areas. MC contamination could result from breached MEC items, with potential transport to environmental media with exposure to human and environmental receptors.

Tables 3-1a through 3-1h present detailed preliminary CSMs for each MRS, including facility and physical profiles (setting, layout, structures, terrain, vegetation, significant features, security), land use and exposure profiles (receptors), ecological (habitat, species) and munition release profiles (types, transport mechanisms, migration routes, pathway analysis).

Diagrams graphically presenting the preliminary CSMs for MEC/MD and MC, showing source, interaction, and receptor are included as Figures A-3-1 through A-3-3. Figure A-3-1 addresses MEC and MD, showing MRSs 1 through 6 grouped, while based on their different scenarios, MRSs 7 and 8 are separated. Figure A-3-2 addresses MC, showing MRSs 1 through 7 grouped, while Figure A-3-3 shows MRS-8 separately.

Impacts to these preliminary CSMs based on the RI findings are discussed in Section 5.0 of this report, where updated or revised CSMs, in both table and diagram format, are presented.

Table 3-1a. Preliminary Conceptual Site Model for MRS-1

Profile Type	Site Characterization
Facility Profile	**Location and Area:** • MRS-1 is approximately 99 acres and is located along the eastern side of the peninsula, east of Atlantic Drive, extending to the beach. MRS-1 includes the 1,000-Yard Impact Area.
	Structures: • Several buildings are located in the MRS. These include two visitor beach houses, and their associated parking lots, as well as Battery Gunnison. The road network includes Atlantic Drive.
	Boundaries: • North: The approximate boundary is the Old Proving Battery Firing Point. • South: The approximate boundary is the southern edge of the 1,000-Yard Impact Area, north of the water treatment facility. • West: The approximate boundary is Atlantic Drive. • East: The boundary is the shoreline of the Atlantic Ocean.
	Security: • The MRS is partially covered by dense vegetation (woody and herbaceous), which naturally limits access to parts of the MRS.
	Utilities: • Utilities are associated with the park beach houses.
Physical Profile	**Topography:** • Elevation is approximately 0 to 15 ft amsl. • Dunal topography is present on parts of the MRS.
	Vegetation: • Beach and dune flora is predominantly characterized by grasses, forbs and stunted shrubs. Inland flora is predominantly characterized by evergreen and mixed maritime forests, with deciduous forests (both maritime and non-maritime) on the western portion of the site.
	Wetlands: • There is one small wetland present in the west central portion of MRS-1.
	Soil: • Beach and dune sands make up all of the Sandy Hook Unit spit. • The dune sand is chiefly medium grained and better sorted than the beach sand. The dunes are partly stabilized and fairly well covered by bushes and grass.
	Hydrology: • The closest surface water body is the Atlantic Ocean. • Except during intense rainfall events, groundwater infiltration is high and surface runoff minimal due to the sandy soils. Therefore, surface water changes are mainly due to tidal action, including daily fluctuations and storm surges.
	Hydrogeology/Geology: • Two major aquifer systems are associated with Fort Hancock: the North Atlantic Coastal Plain aquifer system and the Englishtown aquifer. • Drinking water for the entire Sandy Hook peninsula is supplied by one well completed approximately 880 feet deep into a confined aquifer of the North Atlantic

Table 3-1a. Preliminary Conceptual Site Model for MRS-1	
Profile Type	**Site Characterization**
	Coastal Plain aquifer system. • The drinking water well is in the west-central part of the peninsula, more than 1,500 ft away from the nearest MRS. • Fort Hancock is situated on the New Jersey Coastal Plain, a wedge of unconsolidated sediments. These sediments are clay, silt, sand, and gravel, and represent continental, coastal, or marine deposition.
Land Use and Exposure Profile	**Current Land Use:** • NPS and associated recreational uses • Hiking, fishing, 'treasure hunting (intrusive)', bird watching, swimming, picnicking, bike riding • Some park maintenance facilities
	Cultural, Archaeological and Historical Resources: • Based on previous archaeological investigations, Fort Hancock may include archaeological artifacts, features and sites that are associated with the former military use of Fort Hancock.
	Current Potential Human Receptors: • Residents, employees (NPS, Coast Guard, etc.), construction workers, and visitors (adult/child). Because there are no residences currently in MRS-1, residents of Sandy Hook peninsula would be potential recreational visitors for this site.
	Potential Future Land Use: • NPS has stated that Sandy Hook will remain part of the Gateway National Recreation Area in the future and that no changes to the current land use are projected.
	Potential Future Human Receptors: • No changes are anticipated to the current human receptors.
Ecological Profile	**Degree of Disturbance:** • Primarily undisturbed with minimal trafficked (except for the beach) areas (e.g. during construction of roadways, buildings).
	Habitat Types: • Rare Ecological Communities include: Maritime Holly Forest, Heathland, Primary Dune System, Coastal Dune Woodland. Other types present are evergreen, mixed maritime, and deciduous forests; wetland, dune shrubland, dune grassland, beach and intertidal marine.
	Current Potential Ecological Receptors: • **Mammals:** Red Fox, Raccoon, Virginia Opossum, Eastern Cottontail, Gray Squirrel, Whitetail Deer • **Birds:** Over 340 species of birds use the Sandy Hook peninsula as foraging and resting habitat during spring and fall migration, and the peninsula provides valuable breeding habitat for sensitive species and coastal wintering habitat for significant waterfowl populations. Refer to Table 6-1 of the RI for Threatened and Endangered (T&E) species. • **Reptiles/Amphibians:** Species include Snapping Turtle, Painted Turtle, Spotted Turtle, Eastern Box Turtle, Eastern Mud Turtle, Eastern Hognose Snake, Northern Brown (DeKay's) Snake. Refer to Table 7.4 of the Final Work Plan for Special Concern (SC) species. • **Insects:** Approximately 46 species of butterflies and at least 24 species of

Table 3-1a. Preliminary Conceptual Site Model for MRS-1	
Profile Type	**Site Characterization**
	dragonflies may be present. Refer to Table 7.2 of the Final Work Plan for T&E species. • **Plants:** Beach and dune flora includes grasses, forbs, and stunted shrubs. Inland flora includes evergreen and mixed maritime forests; deciduous forests (both maritime and non-maritime), and a Maritime Holly Forest. Refer to Table 7.1 of the Final Work Plan for T&E/SC species.
Munitions Release Profile	**Munitions Types:** • Table 1-1 in Section 1 lists munitions historically used at Fort Hancock; it is possible that any of these could be present in the MRS.
	Release Mechanisms: • MEC, as UXO or from low order detonations could exist on or under the ground surface from historical proving ground or training operations. DMM may exist from the disposal of discarded munitions (i.e., burial pits). Natural processes such as erosion, wave action or shifting of sand could expose MEC, if present. MC could be present in environmental media from the release of filler materials at low order detonations or from the corrosion of munitions projectiles (casings).
	MEC Density: • MEC density is expected to be concentrated in the former impact area, and perhaps randomly scattered elsewhere.
	Munitions Debris: • Munitions debris may be scattered randomly across the site.
	Associated Munitions Constituents: • Explosives compounds, and these selected metals: antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc.
	Transport Mechanisms/Migration Routes: • MEC/MD: - moving a potential item by a person(s) - disturbance of MEC/MD through construction activities - natural processes such as wave action and beach erosion • MC: - natural processes such as wind and wave action - physical and chemical processes such as infiltration, adsorption, and/or dispersion
	Pathway Analysis: (see Figures A-3-1 and A-3-2) • MEC/MD: - MEC/MD may be present on the surface and in the subsurface; receptors are potentially present and the pathway is considered complete. • MC: - MC may be present in the surface and subsurface soil above background concentrations and could have migrated to surface water, sediment, and groundwater. Receptors are present and these pathways are considered potentially complete.

Table 3-1b. Preliminary Conceptual Site Model for MRS-2	
Profile Type	**Site Characterization**
Facility Profile	**Location and Area:** • MRS-2 is approximately 151 acres and located along the eastern side of the peninsula. Most of the MRS is east of Atlantic Drive, extending to the beach, with a small portion located west of Atlantic Drive. MRS-2 includes the 2,000-Yard Impact Area. • The western part of MRS-2 includes some NPS excluded acreage.
	Structures: • Several buildings are located in the MRS, and are associated with the water treatment facility. The road network includes Atlantic Drive.
	Boundaries: • North: The approximate boundary is the southern edge of the 1,000-Yard Impact area, north of the water treatment facility. • South: The approximate boundary is the southern edge of the 2,000-Yard Impact Area. • West: The boundary is a significant distance west of Atlantic Drive. • East: This boundary is the shoreline of the Atlantic Ocean.
	Security: • The MRS is partially covered by dense vegetation (woody and herbaceous), which naturally limits access to parts of the MRS.
	Utilities: • Utilities are associated with the water treatment facility. There is also buried pipe along the east side of Atlantic Drive associated with beach replenishment activities.
Physical Profile	**Topography:** • Elevation is approximately 0 to 15 ft amsl. • Dunal topography is present on parts of the MRS.
	Vegetation: • Beach and dune flora is predominantly characterized by grasses, forbs and stunted shrubs. Inland flora is predominantly characterized by evergreen and mixed maritime forests, with deciduous forests (both maritime and non-maritime) on the western portion of the site.
	Wetlands: • Wetlands are located in the north central and south/southeast portions of the MRS.
	Soil: • Beach and dune sands make up all of the Sandy Hook Unit spit. • The dune sand is chiefly medium grained and better sorted than the beach sand. The dunes are partly stabilized and fairly well covered by bushes and grass.
	Hydrology: • The closest surface water body is the Atlantic Ocean. • Except during intense rainfall events, groundwater infiltration is high and surface runoff minimal due to the sandy soils. Therefore, surface water changes are mainly due to tidal action, including daily fluctuations and storm surges.
	Hydrogeology/Geology: • See discussion in Table 3-1a.

Table 3-1b. Preliminary Conceptual Site Model for MRS-2	
Profile Type	**Site Characterization**
Land Use and Exposure Profile	**Current Land Use:** • NPS and associated recreational uses. • Hiking, fishing, 'treasure hunting (intrusive)', bird watching, swimming, picnicking, bike riding. • Some park maintenance facilities.
	Cultural, Archaeological and Historical Resources: • Based on previous archaeological investigations, Fort Hancock may include archaeological artifacts, features and sites that are associated with the former military use of Fort Hancock.
	Current Potential Human Receptors: • Residents, employees (NPS, Coast Guard, etc.), construction workers, and visitors (adult/child). Because there are no residences currently in MRS-2, residents of Sandy Hook peninsula would be potential recreational visitors for this site.
	Potential Future Land Use: • NPS has stated that Sandy Hook will remain part of the Gateway National Recreation Area in the future and that no changes to the current land use are projected.
	Potential Future Human Receptors: • No changes are anticipated to the current human receptors.
Ecological Profile	**Degree of Disturbance:** • Primarily undisturbed with minimal trafficked (except for the beach) areas (e.g. during construction of roadways**,** buildings).
	Habitat Types: • Rare Ecological Communities include: Maritime Holly Forest, Heathland, Primary Dune System, Coastal Dune Woodland. Other types present are evergreen, mixed maritime, and deciduous forests; wetland, dune shrubland, dune grassland, beach and intertidal marine.
	Current Potential Ecological Receptors: • See discussion in Table 3-1a.
Munitions Release Profile	**Munitions Types:** • Table 1-1 in Section 1 lists munitions historically used at Fort Hancock; it is possible that any of these could be present in the MRS.
	Release Mechanisms: • MEC, as UXO or from low order detonations could exist on or under the ground surface from historical proving ground or training operations. DMM may exist from the disposal of discarded munitions (i.e., burial pits). Natural processes such as erosion, wave action or shifting of sand could expose MEC, if present. MC could be present in environmental media from the release of filler materials at low order detonations or from the corrosion of munitions projectiles (casings).
	MEC Density: • MEC density is expected to be concentrated in the former impact area, and perhaps randomly scattered elsewhere.
	Munitions Debris: • Munitions debris may be scattered randomly across the site.

Table 3-1b. Preliminary Conceptual Site Model for MRS-2

Profile Type	Site Characterization
	Associated Munitions Constituents: • Explosives compounds, and these selected metals: antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc.
	Transport Mechanisms/Migration Routes: • MEC/MD: - moving a potential item by a person(s) - disturbance of MEC/MD through construction activities - natural processes such as wave action and beach erosion • MC: - natural processes such as wind and wave action - physical and chemical processes such as infiltration, adsorption, and/or dispersion
	Pathway Analysis: (see Figures A-3-1 and A-3-2) • MEC/MD: - MEC/MD may be present on the surface and in the subsurface; receptors are present and the pathway is considered potentially complete. • MC: - MC may be present in the surface and subsurface soil above background concentrations and could have migrated to surface water, sediment, and groundwater. Receptors are present and these pathways are considered potentially complete.

Table 3-1c. Preliminary Conceptual Site Model for MRS-3	
Profile Type	**Site Characterization**
Facility Profile	**Location and Area:** • MRS-3 is approximately 89 acres and located along the eastern side of the peninsula. Most of the MRS is east of Atlantic Drive, extending to the beach, with small portions located west and south of Atlantic Drive. MRS-3 includes the 2,500-Yard Impact Area.
	Structures: • Several buildings/structures are located in the MRS, and are associated with the Nike Missile radar site. The road network includes Atlantic Drive and those roads associated with the radar facility.
	Boundaries: • North: The approximate boundary is the southern edge of the 2,000-Yard Impact area. • South: The approximately the southern edge of the 2,500-Yard Impact Area. • West: The boundary is a significant distance west of Atlantic Drive, and passes through the Nike Missile radar site. • East: The approximate boundary is the shoreline of the Atlantic Ocean.
	Security: • The MRS is partially covered by dense vegetation (woody and herbaceous), which naturally limits access to parts of the MRS.
	Utilities: • Buried pipe along the east side of Atlantic Drive associated with beach replenishment activities. There are also possible abandoned utilities associated with the Nike Missile radar site.
Physical Profile	**Topography:** • Elevation is approximately 0-15 ft amsl. • Dunal topography is present on parts of the MRS.
	Vegetation: • Beach and dune flora is predominantly characterized by grasses, forbs and stunted shrubs. Inland flora is predominantly characterized by evergreen and mixed maritime forests, with deciduous forests (both maritime and non-maritime) on the western portion of the site.
	Wetlands: • There are wetlands located in the northeast portion of the MRS.
	Soil: • Beach and dune sands make up all of the Sandy Hook Unit spit. • The dune sand is chiefly medium grained and better sorted than the beach sand. The dunes are partly stabilized and fairly well covered by bushes and grass.
	Hydrology: • The closest surface water body is the Atlantic Ocean. • Except during intense rainfall events, groundwater infiltration is high and surface runoff minimal due to the sandy soils. Therefore, surface water changes are mainly due to tidal action, including daily fluctuations and storm surges.
	Hydrogeology/Geology: • See discussion in Table 3-1a.

Table 3-1c. Preliminary Conceptual Site Model for MRS-3	
Profile Type	**Site Characterization**
Land Use and Exposure Profile	**Current Land Use:** • NPS and associated recreational uses. • Hiking, fishing, 'treasure hunting (intrusive)', bird watching, swimming, picnicking, bike riding.
	Cultural, Archaeological and Historical Resources: • Based on previous archaeological investigations, Fort Hancock may include archaeological artifacts, features and sites that are associated with the former military use of Fort Hancock.
	Current Potential Human Receptors: • Residents, employees (NPS, Coast Guard, etc.), construction workers, and visitors (adult/child). Because there are no residences currently in MRS-3, residents of Sandy Hook peninsula would be potential recreational visitors for this site.
	Potential Future Land Use: • NPS has stated that Sandy Hook will remain part of the Gateway National Recreation Area in the future and that no changes to the current land use are projected.
	Potential Future Human Receptors: • No changes are anticipated to the current human receptors.
Ecological Profile	**Degree of Disturbance:** • Primarily undisturbed with minimal trafficked (except for the beach) areas (e.g. during construction of roadways, buildings).
	Habitat Types: • Rare Ecological Communities include: Maritime Holly Forest, Heathland, Primary Dune System, Coastal Dune Woodland. Other types present are evergreen, mixed maritime, and deciduous forests; wetland, dune shrubland, dune grassland, beach and intertidal marine.
	Current Potential Ecological Receptors: • See discussion in Table 3-1a.
Munitions Release Profile	**Munitions Types:** • Table 1-1 in Section 1 lists munitions historically used at Fort Hancock; it is possible that any of these could be present in the MRS.
	Release Mechanisms: • MEC, as UXO or from low order detonations could exist on or under the ground surface from historical proving ground or training operations. DMM may exist from the disposal of discarded munitions (i.e., burial pits). Natural processes such as erosion, wave action or shifting of sand could expose MEC, if present. MC could be present in environmental media from the release of filler materials at low order detonations or from the corrosion of munitions projectiles (casings).
	MEC Density: • MEC density is expected to be concentrated in the former impact area, and perhaps randomly scattered on the beach.
	Munitions Debris: • Munitions debris may be scattered randomly across the site.

Table 3-1c. Preliminary Conceptual Site Model for MRS-3	
Profile Type	**Site Characterization**
	Associated Munitions Constituents: • Explosives compounds, and these selected metals: antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc.
	Transport Mechanisms/Migration Routes: • MEC/MD: - moving a potential item by a person(s) - disturbance of MEC/MD through construction activities - natural processes such as wave action and beach erosion • MC: - natural processes such as wind and wave action - physical and chemical processes such as infiltration, adsorption, and/or dispersion
	Pathway Analysis: (see Figures A-3-1 and A-3-2) • MEC/MD: - MEC/MD may be present on the surface and in the subsurface; receptors are present and the pathway is considered potentially complete. • MC: - MC may be present in the surface and subsurface soil above background concentrations and could have migrated to surface water, sediment, and groundwater. Receptors are present and these pathways are considered potentially complete.

Table 3-1d. Preliminary Conceptual Site Model for MRS-4	
Profile Type	**Site Characterization**
Facility Profile	**Location and Area:** • MRS-4 is approximately 73 acres and located along the eastern side of the peninsula. The MRS lies south and east of Atlantic Drive, extending to the beach. MRS-4 includes the 3,000-Yard Impact Area. • The western part of MRS-4 includes NPS excluded acreage.
	Structures: • There are no structures or road networks in the MRS.
	Boundaries: • North: The approximate boundary is the southern edge of the 2,500-Yard Impact area. • South: The approx boundary is the southern edge of the 3,000-Yard Impact Area. • West: The approximate boundary lies south of Atlantic Drive. • East: The approximate boundary is the shoreline of the Atlantic Ocean.
	Security: • The MRS is partially covered by dense vegetation (woody and herbaceous), which naturally limits access to parts of the MRS.
	Utilities: • There are no known utilities in this MRS.
Physical Profile	**Topography:** • Elevation is approximately 0-15 ft amsl. • Dunal topography is present on parts of the MRS.
	Vegetation: • Beach and dune flora is predominantly characterized by grasses, forbs and stunted shrubs. Inland flora is predominantly characterized by evergreen and mixed maritime forests, with deciduous forests (both maritime and non-maritime) on the western portion of the site.
	Wetlands: • There are no wetlands in the MRS.
	Soil: • Beach and dune sands make up all of the Sandy Hook Unit spit. • The dune sand is chiefly medium grained and better sorted than the beach sand. The dunes are partly stabilized and fairly well covered by bushes and grass.
	Hydrology: • The closest surface water body is the Atlantic Ocean. • Except during intense rainfall events, groundwater infiltration is high and surface runoff minimal due to the sandy soils. Therefore, surface water changes are mainly due to tidal action, including daily fluctuations and storm surges.
	Hydrogeology/Geology: • See discussion in Table 3-1a.
Land Use and Exposure Profile	**Current Land Use:** • NPS and associated recreational uses. • Hiking, fishing, 'treasure hunting (intrusive)', bird watching, swimming, picnicking, bike riding.

Table 3-1d. Preliminary Conceptual Site Model for MRS-4	
Profile Type	**Site Characterization**
	Cultural, Archaeological and Historical Resources: • Based on previous archaeological investigations, Fort Hancock may include archaeological artifacts, features and sites that are associated with the former military use of Fort Hancock.
	Current Potential Human Receptors: • Residents, employees (NPS, Coast Guard, etc.), construction workers, and visitors (adult/child). Because there are no residences currently in MRS-4, residents of Sandy Hook peninsula would be potential recreational visitors for this site.
	Potential Future Land Use: • NPS has stated that Sandy Hook will remain part of the Gateway National Recreation Area in the future and that no changes to the current land use are projected.
	Potential Future Human Receptors: • No changes are anticipated to the current human receptors.
Ecological Profile	**Degree of Disturbance:** • Primarily undisturbed with minimal trafficked (except for the beach) areas (e.g. during construction of roadways, buildings).
	Habitat Types: • Rare Ecological Communities include: Maritime Holly Forest, Heathland, Primary Dune System, Coastal Dune Woodland. Other types present are evergreen, mixed maritime, and deciduous forests; wetland, dune shrubland, dune grassland, beach and intertidal marine.
	Current Potential Ecological Receptors: • See discussion in Table 3-1a.
Munitions Release Profile	**Munitions Types:** • Table 1-1 in Section 1 lists munitions historically used at Fort Hancock; it is possible that any of these could be present in the MRS.
	Release Mechanisms: • MEC, as UXO or from low order detonations could exist on or under the ground surface from historical proving ground or training operations. DMM may exist from the disposal of discarded munitions (i.e., burial pits). Natural processes such as erosion, wave action or shifting of sand could expose MEC, if present. MC could be present in environmental media from the release of filler materials at low order detonations or from the corrosion of munitions projectiles (casings).
	MEC Density: • MEC density is expected to be concentrated in the former impact area, and perhaps randomly scattered elsewhere.
	Munitions Debris: • Munitions debris may be scattered randomly across the site.
	Associated Munitions Constituents: • Explosives compounds, and these selected metals: antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc.

Table 3-1d. Preliminary Conceptual Site Model for MRS-4	
Profile Type	**Site Characterization**
	Transport Mechanisms/Migration Routes: • MEC/MD: - moving a potential item by a person(s) - disturbance of MEC/MD through construction activities - natural processes such as wave action and beach erosion • MC: - natural processes such as wind and wave action - physical and chemical processes such as infiltration, adsorption, and/or dispersion
	Pathway Analysis: (see Figures A-3-1 and A-3-2) • MEC/MD: - MEC/MD may be present on the surface and in the subsurface; receptors are present and the pathway is considered potentially complete. • MC: - MC may be present in the surface and subsurface soil above background concentrations and could have migrated to surface water, sediment, and groundwater. Receptors are present and these pathways are considered potentially complete.

<table>
<tr><th colspan="2">Table 3-1e. Preliminary Conceptual Site Model for MRS-5</th></tr>
<tr><th>Profile Type</th><th>Site Characterization</th></tr>
<tr><td rowspan="5">Facility Profile</td><td>Location and Area:
• MRS-5 is approximately 205 acres and is located along the eastern side of the peninsula. Most of the MRS lies east of Hartshorne Drive, extending to the beach. A small portion of the MRS lies west of Hartshorne Drive. MRS-5 includes the 3-Mile Impact Area.
• Large portions of the northern and southwestern part of MRS-5 are NPS excluded areas where little investigation could be conducted.</td></tr>
<tr><td>Structures:
• Several buildings are located in the MRS. These include buildings associated with the former Nike missile site, as well as a visitor beach house, an NPS Ranger station, and their respective parking lots. The road network includes Hawthorne Drive, as well as the access road for the Fishing Beach.</td></tr>
<tr><td>Boundaries:
• North: The approximate boundary is the southern edge of the 3,000-Yard Impact Area.
• South: The approximate boundary is the southern edge of the 3-Mile Impact Area.
• West: The approximate boundary is Hawthorne Road.
• East: The approximate boundary is the shoreline of the Atlantic Ocean.</td></tr>
<tr><td>Security:
• The MRS is partially covered by dense vegetation (woody and herbaceous), which naturally limits access to parts of the MRS. Additionally, fencing and gates restricting public access are present in the Nike missile site.</td></tr>
<tr><td>Utilities:
• Along Hawthorne Drive, overhead electric, telephone and cable lines, and buried pipes associated with beach replenishment activities. Utilities are associated with the visitor beach house, NPS Ranger station and Nike missile site structures.</td></tr>
<tr><td rowspan="4">Physical Profile</td><td>Topography:
• Elevation is approximately 0 to15 ft amsl.
• Dunal topography is present on parts of the MRS.</td></tr>
<tr><td>Vegetation:
• Beach and dune flora is predominantly characterized by grasses, forbs and stunted shrubs. Inland flora is predominantly characterized by evergreen and mixed maritime forests, with deciduous forests (both maritime and non-maritime) on the western portion of the site.</td></tr>
<tr><td>Wetlands:
• Wetlands are present to the north and south of the Fishing Beach access road, as well as the southwest corner of the MRS.
• Wetlands are also located around and adjacent to the Nike missile pond.</td></tr>
<tr><td>Soil:
• Beach and dune sands make up all of the Sandy Hook Unit spit.
• The dune sand is chiefly medium grained and better sorted than the beach sand. The dunes are partly stabilized and fairly well covered by bushes and grass.</td></tr>
</table>

Table 3-1e. Preliminary Conceptual Site Model for MRS-5	
Profile Type	**Site Characterization**
	Hydrology: • Nike Pond is located in the south-central portion of the MRS. • Except during intense rainfall events, groundwater infiltration is high and surface runoff minimal due to the sandy soils. Therefore, surface water changes are mainly due to tidal action, including daily fluctuations and storm surges.
	Hydrogeology/Geology: • See discussion in Table 3-1a.
Land Use and Exposure Profile	**Current Land Use:** • NPS and associated recreational uses. • Hiking, fishing, 'treasure hunting (intrusive)', bird watching, swimming, picnicking, bike riding. • Some park maintenance activities.
	Cultural, Archaeological and Historical Resources: • Based on previous archaeological investigations, Fort Hancock may include archaeological artifacts, features and sites that are associated with the former military use of Fort Hancock.
	Current Potential Human Receptors: • Residents, employees (NPS, Coast Guard, etc.), construction workers, and visitors (adult/child). Because there are no residences currently in MRS-5, residents of Sandy Hook peninsula would be potential recreational visitors for this site.
	Potential Future Land Use: • NPS has stated that Sandy Hook will remain part of the Gateway National Recreation Area in the future and that no changes to the current land use are projected.
	Potential Future Human Receptors: • No changes are anticipated to the current human receptors.
Ecological Profile	**Degree of Disturbance:** • Primarily undisturbed with minimal trafficked (except for the beach) areas (e.g. during construction of roadways, buildings).
	Habitat Types: • Rare Ecological Communities include: Maritime Holly Forest, Heathland, Primary Dune System, Coastal Dune Woodland. Other types present are evergreen, mixed maritime, and deciduous forests; wetland, dune shrubland, dune grassland, beach and intertidal marine.
	Current Potential Ecological Receptors: • See discussion in Table 3-1a.
Munitions Release Profile	**Munitions Types:** • Table 1-1 in Section 1 lists munitions historically used at Fort Hancock; it is possible that any of these could be present in the MRS.

Table 3-1e. Preliminary Conceptual Site Model for MRS-5

Profile Type	Site Characterization
	Release Mechanisms: • MEC, as UXO or from low order detonations could exist on or under the ground surface from historical proving ground or training operations. DMM may exist from the disposal of discarded munitions (i.e., burial pits). Natural processes such as erosion, wave action or shifting of sand could expose MEC, if present. MC could be present in environmental media from the release of filler materials at low order detonations or from the corrosion of munitions projectiles (casings).
	MEC Density: • MEC density is expected to be concentrated in the former impact area, and perhaps randomly scattered elsewhere.
	Munitions Debris: • Munitions debris may be scattered randomly across the site.
	Associated Munitions Constituents: • Explosives compounds, and these selected metals: antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc.
	Transport Mechanisms/Migration Routes: • MEC/MD: - moving a potential item by a person(s) - disturbance of MEC/MD through construction activities - natural processes such as wave action and beach erosion • MC: - natural processes such as wind and wave action - physical and chemical processes such as infiltration, adsorption, and/or dispersion
	Pathway Analysis: (see Figures A-3-1 and A-3-2) • MEC/MD: - MEC/MD may be present on the surface and in the subsurface; receptors are present and the pathway is considered potentially complete. • MC: - MC may be present in the surface and subsurface soil above background concentrations and could have migrated to surface water, sediment, and groundwater. Receptors are present and these pathways are considered potentially complete.

Table 3-1f. Preliminary Conceptual Site Model for MRS-6

Profile Type	Site Characterization
Facility Profile	**Location and Area:** • MRS-6 is approximately 90 acres and is located along the eastern side of the peninsula. Most of the MRS lies east of Hartshorne Drive, extending to the beach. A small portion of the MRS lies west of Hartshorne Drive. MRS-6 includes the 3.75-Mile Impact Area.
	Structures: • Multiple buildings are located in the MRS. These include the former Sandy Hook Visitor Center, as well as a visitor beach house/restaurant (seasonal), and its associated parking lot. The road network includes Hawthorne Drive.
	Boundaries: • North: The approximate boundary is the southern edge of the 3-Mile Impact Area. • South: The approx boundary is the southern edge of the 3.75-Mile Impact Area. • West: The approximate boundary is Hawthorne Road. • East: The approximate boundary is the shoreline of the Atlantic Ocean.
	Security: • The MRS is partially covered by dense vegetation (woody and herbaceous), which naturally limits access to parts of the MRS.
	Utilities: • Along Hawthorne Drive, overhead electric, telephone and cable lines, and buried pipes associated with beach replenishment activities. Utilities are associated with the former Sandy Hook Visitor Center and the visitor beach house.
Physical Profile	**Topography:** • Elevation is approximately 0-15 ft amsl. • Dunal topography is present on parts of the MRS.
	Vegetation: • Beach and dune flora is predominantly characterized by grasses, forbs and stunted shrubs. Inland flora is predominantly characterized by evergreen and mixed maritime forests, with deciduous forests (both maritime and non-maritime) on the western portion of the site.
	Wetlands: • There are no wetlands in the MRS.
	Soil: • Beach and dune sands make up all of the Sandy Hook Unit spit. • The dune sand is chiefly medium grained and better sorted than the beach sand. The dunes are partly stabilized and fairly well covered by bushes and grass.
	Hydrology: • The closest surface water body is the Atlantic Ocean. • Except during intense rainfall events, groundwater infiltration is high and surface runoff minimal due to the sandy soils. Therefore, surface water changes are mainly due to tidal action, including daily fluctuations and storm surges.
	Hydrogeology/Geology: • See discussion in Table 3-1a.

Table 3-1f. Preliminary Conceptual Site Model for MRS-6	
Profile Type	**Site Characterization**
Land Use and Exposure Profile	**Current Land Use:** • NPS and associated recreational uses. • Hiking, fishing, 'treasure hunting (intrusive)', bird watching, swimming, picnicking, bike riding. • Some park maintenance facilities.
	Cultural, Archaeological and Historical Resources: • Based on previous archaeological investigations, Fort Hancock may include archaeological artifacts, features and sites that are associated with the former military use of Fort Hancock.
	Current Potential Human Receptors: • Residents, employees (NPS, Coast Guard, etc.), construction workers, and visitors (adult/child). Because there are no residences currently in MRS-6, residents of Sandy Hook peninsula would be potential recreational visitors for this site.
	Potential Future Land Use: • NPS has stated that Sandy Hook will remain part of the Gateway National Recreation Area in the future and that no changes to the current land use are projected.
	Potential Future Human Receptors: • No changes are anticipated to the current human receptors.
Ecological Profile	**Degree of Disturbance:** • Primarily undisturbed with minimal trafficked (except for the beach) areas (e.g. during construction of roadways, buildings).
	Habitat Types: • Rare Ecological Communities include: Maritime Holly Forest, Heathland, Primary Dune System, Coastal Dune Woodland. Other types present are evergreen, mixed maritime, and deciduous forests; wetland, dune shrubland, dune grassland, beach and intertidal marine.
	Current Potential Ecological Receptors: • See discussion in Table 3-1a.
Munitions Release Profile	**Munitions Types:** • Table 1-1 in Section 1 lists munitions historically used at Fort Hancock; it is possible that any of these could be present in the MRS.
	Release Mechanisms: • MEC, as UXO or from low order detonations could exist on or under the ground surface from historical proving ground or training operations. DMM may exist from the disposal of discarded munitions (i.e., burial pits). Natural processes such as erosion, wave action or shifting of sand could expose MEC, if present. MC could be present in environmental media from the release of filler materials at low order detonations or from the corrosion of munitions projectiles (casings).
	MEC Density: • MEC density is expected to be concentrated in the former impact area, and perhaps randomly scattered elsewhere.
	Munitions Debris: • Munitions debris may be scattered randomly across the site.

Table 3-1f. Preliminary Conceptual Site Model for MRS-6

Profile Type	Site Characterization
	Associated Munitions Constituents: • Explosives compounds, and these selected metals: antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc.
	Transport Mechanisms/Migration Routes: • MEC/MD: - moving a potential item by a person(s) - disturbance of MEC/MD through construction activities - natural processes such as wave action and beach erosion • MC: - natural processes such as wind and wave action - physical and chemical processes such as infiltration, adsorption, and/or dispersion
	Pathway Analysis: (see Figures A-3-1 and A-3-2) • MEC/MD: - MEC/MD may be present on the surface and in the subsurface; receptors are present and the pathway is considered potentially complete. • MC: - MC may be present in the surface and subsurface soil above background concentrations and could have migrated to surface water, sediment, and groundwater. Receptors are present and these pathways are considered potentially complete.

Table 3-1g. Preliminary Conceptual Site Model for MRS-7

Profile Type	Site Characterization
Facility Profile	**Location and Area:** • MRS-7, known as the Livens Discovery Area, is approximately 29 acres and located approximately in the middle of MRS-5. Most of MRS-7 lies east of Hartshorne Drive, with small portions of the MRS located to the west of Hartshorne Drive and north of the Fishing Beach access road. • Most of the MRS-7 acreage is NPS excluded area.
	Structures: • MRS-7 contains no structures. Historically, the MRS contained munitions storage bunkers.
	Boundaries: • MRS-7 is a 600 foot radius circle centered on the location of the former munitions storehouse, with the boundary based on the hazard fragmentation distance of a Livens projectile plus an investigation buffer.
	Security: • The MRS is mostly covered by dense vegetation (woody and herbaceous), which naturally limits access to parts of the MRS.
	Utilities: • Along Hawthorne Drive, overhead electric, telephone and cable lines, and buried pipes associated with beach replenishment activities.
Physical Profile	**Topography:** • Elevation is approximately 0-15 ft amsl. • Dunal topography is present on parts of the MRS.
	Vegetation: • Flora is predominantly characterized by evergreen and mixed maritime forests, with deciduous forests (both maritime and non-maritime) existing on most of the site.
	Wetlands: • There are wetlands in the eastern, northwest and southwest portions of the MRS.
	Soil: • Beach and dune sands make up all of the Sandy Hook Unit spit. • The dune sand is chiefly medium grained and better sorted than the beach sand. The dunes are partly stabilized and fairly well covered by bushes and grass.
	Hydrology: • The closest surface water bodies are the Nike Missile pond and the Atlantic Ocean. • Except during intense rainfall events, groundwater infiltration is high and surface runoff minimal due to the sandy soils. Therefore, surface water changes are mainly due to tidal action, including daily fluctuations and storm surges.
	Hydrogeology/Geology: • See discussion in Table 3-1a.
Land Use and Exposure Profile	**Current Land Use:** • NPS and associated recreational uses. • Hiking, bird watching, picnicking, bike riding. • Some park maintenance facilities.

Table 3-1g. Preliminary Conceptual Site Model for MRS-7	
Profile Type	**Site Characterization**
	Cultural, Archaeological and Historical Resources: • Based on previous archaeological investigations, Fort Hancock may include archaeological artifacts, features and sites that are associated with the former military use of Fort Hancock.
	Current Potential Human Receptors: • Residents, employees (NPS, Coast Guard, etc.), construction workers, and visitors (adult/child). Because there are no residences currently in MRS-7, residents of Sandy Hook peninsula would be potential recreational visitors for this site.
	Potential Future Land Use: • NPS has stated that Sandy Hook will remain part of the Gateway National Recreation Area in the future and that no changes to the current land use are projected.
	Potential Future Human Receptors: • No changes are anticipated to the current human receptors.
Ecological Profile	**Degree of Disturbance:** • Primarily undisturbed with minimal trafficked areas due to natural barriers.
	Habitat Types: • Rare Ecological Communities include: Maritime Holly Forest, Heathland, Primary Dune System, Coastal Dune Woodland. Other types present are evergreen, mixed maritime, and deciduous forests; wetland, dune shrubland, dune grassland, beach and intertidal marine.
	Current Potential Ecological Receptors: • See discussion in Table 3-1a.
Munitions Release Profile	**Munitions Types:** • Table 1-1 in Section 1 lists munitions historically used at Fort Hancock; it is possible that any of these could be present in the MRS.
	Release Mechanisms: • MEC, as UXO or from low order detonations could exist on or under the ground surface from historical proving ground or training operations. DMM may exist from the disposal of discarded munitions (i.e., burial pits). Natural processes such as erosion, wave action or shifting of sand could expose MEC, if present. MC could be present in environmental media from the release of filler materials at low order detonations or from the corrosion of munitions projectiles (casings). • The fire in the storage bunker is an additional release mechanism for MRS-7.
	MEC Density: • MEC density is expected to be scattered throughout the MRS based on ‘kick-out’ from the explosion of the former storehouse.
	Munitions Debris: • Munitions debris may be scattered across the site.
	Associated Munitions Constituents: • Explosives compounds, and these selected metals: antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc.

Table 3-1g. Preliminary Conceptual Site Model for MRS-7

Profile Type	Site Characterization
	Transport Mechanisms/Migration Routes: • MEC/MD: - moving a potential item by a person(s) - disturbance of MEC/MD through construction activities - natural processes such as wave action and beach erosion • MC: - natural processes such as wave action due to storm surge - physical and chemical processes such as infiltration, adsorption, and/or dispersion
	Pathway Analysis: (see Figures A-3-1 and A-3-2) • MEC/MD: - MEC/MD may be present on the surface and in the subsurface as MRS-7 is a possible disposal area; receptors are present and the pathway is considered potentially complete. • MC: - MC may be present in the surface and subsurface soil above background concentrations and could have migrated to surface water, sediment, and groundwater. Receptors are present and these pathways are considered potentially complete.

Table 3-1h. Preliminary Conceptual Site Model for MRS-8

Profile Type	Site Characterization
Facility Profile	**Location and Area:** • MRS-8 is approximately 154 acres, and is a marine MRS located in the Atlantic Ocean along the east coast of the peninsula. It is parallel to the former proving ground and impact locations. The MRS extends eastward into the ocean approximately 100 yards, reflecting a 6-foot depth contour.
	Structures: • N/A
	Boundaries: • North: The approximate boundary extends north of the 9-Gun Battery, located inland to the west. • South: The approx boundary is the southern edge of the 3.75-Mile Impact Area. • West: The approximate boundary is the peninsula shoreline. • East: The approximate boundary is 100 yards east of the peninsula shoreline.
	Security: • All of the MRS is accessible to the public.
	Utilities: • N/A
Physical Profile	**Topography:** • N/A.
	Vegetation: • N/A.
	Wetlands: • N/A
	Soil: • Beach sand.
	Hydrology: • Surface water hydrology for MRS-8 is dependent on tidal action, including daily fluctuations and storm surges.
	Hydrogeology/Geology: • Shallow groundwater is influenced by the sea water. However, the deep drinking water aquifer (approximately 880 ft bgs) is not impacted by sea water, allowing it to be a potable source.
Use and Exposure Profile	**Current Land Use:** • NPS and associated recreational uses. • Fishing, swimming, boating.
	Cultural, Archaeological and Historical Resources: • Based on previous archaeological investigations, Fort Hancock may include archaeological artifacts, features and sites that are associated with the former military use of Fort Hancock.
	Current Potential Human Receptors: • Residents, employees (NPS, Coast Guard, etc.), and visitors (adult/child). Because there are no residences currently in MRS-8, residents of Sandy Hook peninsula would be potential recreational users of the water.

Table 3-1h. Preliminary Conceptual Site Model for MRS-8	
Profile Type	**Site Characterization**
	Potential Future Use: • NPS has stated that Sandy Hook will remain part of the Gateway National Recreation Area in the future and that no changes to the current land use are projected.
	Potential Future Human Receptors: • No changes are anticipated to the current human receptors.
Ecological Profile	**Degree of Disturbance:** • Primarily undisturbed with partially trafficked areas due to swimming, surfing, fishing, and boating. Significant storms will impact the sea bottom topography
	Habitat Types: • Beach and intertidal marine.
	Current Potential Ecological Receptors: • **Mammals:** Harbor seals, hooded seals, gray seals, humpback whales, right whales, finback whales and bottlenose dolphins. Refer to Table 7.5 of the Final Work Plan for T&E species. • **Birds/Waterfowl: S**urf scoters, black scoters, common loon, brant, red-breasted mergansers, greater scaup, American black duck, bufflehead, gulls, seabirds, and bald eagles. Refer to Table 6-1 of the RI for T&E species. • **Reptiles/Amphibians:** Leatherback sea turtles, Atlantic/Kemp's Ridley sea turtles, Atlantic loggerhead sea turtles, green sea turtles, and Hawksbill sea turtles. The diamondback terrapin is listed as a special concern species in New Jersey. Refer to Table 7.4 of the Final Work Plan for T&E species. • **Fish:** Atlantic salmon; Atlantic sea herring; Atlantic butterfish; Atlantic cod; Pollock; whiting; red hake; black sea bass; Spanish, Atlantic, and king mackerel; winter, summer, yellowtail; windowpane flounder; bluefin and skipjack tuna; long-finned squid; skates and rays; sand tiger sharks; dusky sharks; shortfin mako sharks; sandbar sharks; tiger sharks; common thresher sharks; white sharks; and blue sharks. Refer to Table 7.5 of the Final Work Plan for T&E species. • **Invertebrates:** Ribbon worms, mole crabs, blue mussels, Atlantic surf clams, annelid worms, wedge clams, knobbed and channel whelks, moon snails, starfish, horseshoe, hermit, spider crabs, American oysters, blue crabs, ribbed mussels, and hard and soft clams. Refer to Table 7.2 of the Final Work Plan for T&E/SC species.
Munitions Release Profile	**Munitions Types:** • Table 1-1 in Section 1 lists munitions historically used at Fort Hancock; it is possible that any of these could be present in the MRS.
	Release Mechanisms: • MEC, as UXO or from low order detonations could exist on or under the ground surface from historical proving ground or training operations. DMM may exist from the disposal of discarded munitions (i.e., burial pits). Natural processes such as erosion, wave action or shifting of sand could expose MEC, if present. MC could be present in environmental media from the release of filler materials at low order detonations or from the corrosion of munitions projectiles (casings).
	MEC Density: • MEC density is expected to be randomly scattered throughout the MRS due to wave action.

Table 3-1h. Preliminary Conceptual Site Model for MRS-8

Profile Type	Site Characterization
	Munitions Debris: • Munitions debris may be scattered randomly across the sea floor.
	Associated Munitions Constituents: • Explosives compounds, and these selected metals: antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc.
	Transport Mechanisms/Migration Routes: • MEC/MD: - moving a potential item by a person(s) - natural processes such as wave action and beach erosion • MC: - natural processes such as wave action and beach erosion - physical and chemical processes such as infiltration, adsorption, and/or dispersion
	Pathway Analysis: (see Figures A-3-1 and A-3-3) • MEC/MD: - MEC/MD may be present on the surface (sea floor) and in the subsurface/sediment; receptors are present and the pathway is considered complete. • MC: - MC may be present in the surface water and the subsurface/sediment above background concentrations and could migrate to shallow groundwater. Receptors are potentially present and these pathways are considered complete.

3.2 Data Needs and Data Quality Objectives

3.2.1 <u>Data Needs</u>

Data were needed to achieve the site characterization goal of assessing the nature and extent of MEC and MC contamination caused by the past military activities at Fort Hancock and to recommend whether further CERCLA actions are warranted. Data obtained included DGM surveys, intrusive investigations to identify location, density, and types of MEC, and environmental sampling to determine the distribution and concentrations of metals and explosives in soil, sediment, surface water, and groundwater. These data were used to quantify risks to human health and the environment and assess MEC hazards.

3.2.2 <u>Data Quality Objectives</u>

Data quality objectives (DQOs) are qualitative and quantitative statements that specify the quality and level of data required to support the decision-making processes for a project. The *Data Quality Objectives Process for Hazardous Waste Site Investigations (QA/G-4HW)* (US Environmental Protection Agency, 2000a) provides general, non-mandatory guidance on developing DQOs for environmental data collection operations in support of hazardous waste site investigations. USACE's TPP process (USACE EM 200-1-2) closely mirrors EPA's 7-step DQO process, and the DQOs for Fort Hancock have been refined through three TPP meetings.

The DQOs are based on the overall objective of characterizing the nature and extent of MEC and MC contamination and the data needed to accomplish this objective.

Table 3-2a presents the overall DQOs for the DGM and intrusive investigation, the primary means of identifying the nature and extent of MEC contamination. Tables 3-2b, c, and d present the DQOs for soil, sediment/surface water, and groundwater sampling activities, respectively, the primary means for identifying the nature and extent of MC contamination. All DQOs were discussed in the TPP meetings and any comments received from stakeholders were addressed; final versions of all DQOs were outlined in the Final Work Plan (ERT, 2010).

All DQOs were met unless specifically discussed in Section 5.2. A data quality assessment is provided in Section 5.3.5.

Table 3-2a. Data Quality Objectives – Digital Geophysical Mapping/Intrusive Investigation

DQO Element	Site-Specific DQO Statement
Project Objective(s) Satisfied	To determine if further actions are required to support the continued use of the site for recreational activities
Data User Perspective(s)	To obtain data that satisfy compliance, risk, and if needed, remedy requirements
Contaminant or Characteristic of Interest	To characterize the nature and extent of MEC
Media of Interest	**MEC in Soil**
Required Sampling Locations or Areas and Depths	A. Use Visual Sample Plan (VSP) in Target Search Mode to design transect placement (random parallel transect sampling). See Figure A-4-3. Transect design ensures 100% chance of detecting a target. B. Perform the DGM of transects. Pick anomalies. C. Use VSP to do Geostatistical Mapping of Anomaly Density (Cluster Analysis) on anomaly locations. VSP identifies 'clusters' of certain density (to find expected areas of high MEC/MD density that might signify target or other areas). D. Organize the MRS into areas based on the contouring: higher density areas (clusters), and the remainder of the MRS acreage outside of the cluster areas. These areas are then tested as described in the next element.
Number of Samples Required	E. Test each cluster using UXO Estimator to obtain a minimum DGM coverage in acres. The hypothesis of 5 UXO/acre and 95% confidence (agreed to by the project team and included in the Work Plan) are used. Section 4.1.3.3 provides a detailed explanation of UXO Estimator, hypothesis, and confidence. F. Use VSP to randomly locate the grids inside the cluster. G. Perform DGM of the grids and dig all anomalies. Note that depth is whatever the associated munition depth is to a practical maximum of 4 feet below ground surface (bgs) based on hand digging (no powered digging equipment permitted) and shallow water table. H. Input MEC/MD findings, hypothesis of 5 UXO/acre, cluster area, and

Table 3-2a. Data Quality Objectives – Digital Geophysical Mapping/Intrusive Investigation

DQO Element	Site-Specific DQO Statement
	grid area into UXO Estimator. It outputs: 1. Average UXO density in the cluster. 2. UXO density at a 95% confidence level 3. Confidence that the UXO density is equal to or less than the hypothesis of 5 UXO/acre.
Reference Concentration of Interest or Other Performance Criteria	See items 5 and 6 above
Sampling Method	VSP and UXO Estimator software tools for designing statistically based investigations
Analytical Method	Not Applicable (NA)

Table 3-2b. Data Quality Objectives – Soil Sampling

DQO Element	Site-Specific DQO Statement
Project Objective(s) Satisfied	To determine if further actions are required to support the continued use of the site for recreational activities
Data User Perspective(s)	To obtain data that satisfy compliance, risk, and if needed, remedy requirements
Contaminant or Characteristic of Interest	To characterize the nature and extent of MC contamination. Metals (to include antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc) and Explosives.
Media of Interest	**Soil**
Required Sampling Locations or Areas and Depths	Soil samples will only be collected in areas where there is visible evidence of energetic material, e.g., munitions items which are breached. Also, in areas of significant MD, where at least 50% of the munition could be identified by UXO Techs, such that an assumption of MC in the vicinity could be tested by taking a sample. Depth is whatever the associated munition depth is to a practical maximum of 4 feet bgs based on hand digging (no powered digging equipment permitted). However, identified MC contamination greater than 4 feet will be characterized. In the Livens MRS-7, 21 random discrete grab samples using Visual Sample Plan software. Depth is 0-6 inches (surface samples).
Number of Samples Required	To obtain a sufficient number of samples to characterize nature and extent of MC soil contamination at MRS-7 where previous history indicates potential for soil contamination: In the Livens MRS-7, 21 random discrete grab samples.
Reference Concentration of Interest or Other Performance Criteria	Human Health: USEPA Regional Screening Levels (RSLs) and NJ Soil Remediation Standards. Ecological Risk: USEPA's Eco-Soil Screening Levels and NJDEP's Ecological Screening Criteria table

Table 3-2b. Data Quality Objectives – Soil Sampling

DQO Element	Site-Specific DQO Statement
Sampling Method	Obtain discrete surface or sub-surface soil using hand trowels or hand auger depending on depth.
Analytical Method	Preparatory methods for metals collected as grab samples by SW-846 3050B/7471A and analytical methods by SW-846 6010B/7471A; preparatory methods for metals collected by MIS by Accutest SOP MET 104.9, Appendix A and analytical methods by SW-846 6010B/7471A; and explosives preparatory method by SW-846 8330B Appendix A and analytical method by SW-846 8330B.

Table 3-2c. Data Quality Objectives – Sediment and Surface Water Sampling

DQO Element	Site-Specific DQO Statement
Project Objective(s) Satisfied	To determine if further actions are required to support the continued use of the site for recreational activities and whether ecological risk is present
Data User Perspective(s)	To obtain data that satisfy compliance, risk, and if needed, remedy requirements
Contaminant or Characteristic of Interest	To characterize the nature and extent of MC contamination. Metals (to include antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc) and Explosives.
Media of Interest	**Surface Water and Sediment**
Required Sampling Locations or Areas and Depths	Co-located surface water and sediment samples will be collected from Nike Pond located within MRS-5 to focus on areas of surface run-off from potentially contaminated soil. Three co-located samples will be collected from Nike pond in areas different from the SI sampling. For each 0-6 inch deep sediment sample associated with a surface water location, an additional co-located subsurface sediment sample will be collected approximately 6-12 inches deep.
Number of Samples Required	Three co-located surface water and sediment samples from Nike pond will be sufficient to assess whether surface run-off contributes MC contamination to the pond.
Reference Concentration of Interest or Other Performance Criteria	Human Health: USEPA RSLs and NJ Soil Remediation Standards. Ecological Risk: USEPA's Eco-Soil Screening Levels and NJDEP's Ecological Screening Criteria table
Sampling Method	Obtain discrete sediment sample using hand trowels and/or hand auger depending on depth in accordance with the Standard Operating Procedures (SOP) in the UFP-QAPP. Collect surface water in same location (co-located) in accordance with SOPs in UFP-QAPP.
Analytical Method	Metals preparatory methods by SW-846 3050B/7470A/7471A and analytical methods by SW-846 6010B/7470A/7471A; and explosives preparatory and analytical method by SW-846 8330B.

Table 3-2d. Data Quality Objectives – Groundwater Sampling	
DQO Element	**Site-Specific DQO Statement**
Project Objective(s) Satisfied	To determine if further actions are required to support the continued use of the site for recreational activities
Data User Perspective(s)	To obtain data that satisfy compliance, risk, and if needed, remedy requirements
Contaminant or Characteristic of Interest	To characterize the nature and extent of MC contamination in the shallow groundwater. Metals (to include antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc) and Explosives.
Media of Interest	**Groundwater**
Required Sampling Locations or Areas and Depths	Sample 4 existing shallow groundwater wells. Wells GW-2e, GW-11, GW-17, and s909 will be sampled.
Number of Samples Required	To obtain a sufficient number of samples to characterize baseline groundwater conditions. In addition, as a screening level evaluation, use the following process to assess the potential for possible soil “hot spots” to impact groundwater (this assumes that individual sample results represent the mean concentration over a 0.5 acre source area through the entire thickness of the vadose zone): 1.) Compare soil detections to the Protection of Groundwater SSLs, adjusted by a dilution attenuation factor (DAF) of 20. For analytes with MCLs, use the MCL-based SSL. If these exceed, then, 2.) If a detection exceeds the SSL (DAF = 20), use soil pH or total organic carbon data to calculate a site-specific soil screening level. If an analyte has a MCL value, then the target groundwater concentration will be the MCL. If the analyte does not have a MCL, then the target groundwater concentration will be the tap water RSL. Use a DAF of 20 to convert the target groundwater concentration to the target leachate concentration. 3.) If a sample result still exceeds the site-specific SSL, collect a soil sample for Synthetic Precipitate Leaching Procedure (SPLP) analysis. If that leachate concentration exceeds the target groundwater concentration multiplied by a DAF of 20, then further groundwater investigation may be warranted. If the leachate concentration is less than or equal to the target groundwater concentration adjusted by a DAF of 20, then no further evaluation of the soil-to-groundwater migration pathway will be performed. Note that the evaluation of the soil-to-groundwater migration pathway would not be performed for those metals that appear to represent background conditions. The follow-on groundwater investigation would include installing additional wells and collecting more samples at the “hot spot” area. This

Table 3-2d. Data Quality Objectives – Groundwater Sampling

DQO Element	Site-Specific DQO Statement
	investigation would entail a maximum of 3 shallow temporary wells.
Reference Concentration of Interest or Other Performance Criteria	Human Health: USEPA Regional Screening Levels (RSLs), including MCLs, Protection of groundwater SSLs, and Tap water RSLs. Ecological Risk: USEPA's Eco-Screening Levels and NJDEP's Ecological Screening Criteria table
Sampling Method	Obtain groundwater samples or install groundwater wells in accordance with SOPs in UFP-QAPP
Analytical Method	Metals preparatory methods by SW-846 3050B/7470A and analytical methods by SW-846 6010B/7470A; and explosives preparatory and analytical method by SW-846 8330B.

4.0 CHARACTERIZATION OF MUNITIONS AND EXPLOSIVES OF CONCERN AND MUNITIONS CONSTITUENTS

This section describes the RI field activities performed. All activities were performed in accordance with the Work Plan (ERT, 2010).

To comprehensively characterize the nature and extent of MEC hazards and any potential MC contamination, the RI focused on eight MRSs (7 terrestrial and one marine based) and two PAOIs (9-Gun Battery and Kingman-Mills Battery). Figures A-4-1 and A-4-2 present larger scale views of the northern and southern halves of the site, respectively, detailing these areas.

4.1 Munitions and Explosives of Concern Characterization

4.1.1 General Approach

4.1.1.1 Equipment

Geophysical and navigational equipment used to identify locations for intrusive investigation both on land and in the water are listed below.

- G-858 Gradiometer: The G-858 is a split-beam cesium vapor (non-radioactive) magnetometer that produces a measurement of the ambient magnetic field in units of nanoTeslas (nT). Measurements of the total magnetic field are collected using two sensors spaced 1.0-m apart in the vertical orientation, with the lower sensor kept 6 inches above the ground surface. In this way the total field and the vertical magnetic gradient are recorded concurrently. The instrument was set to collect data at a maximum rate of 10 readings per second. The G-858 was integrated with a HiperGa Real Time Kinematic Global Positioning System (RTK GPS). See photos 01, 07, 09, 10, in Appendix H-1.
- G-882 Transverse Gradiometer: The G-882 Transverse Gradiometer (TVG) was used for the marine geophysical survey in MRS 8 (See photo 02, Appendix H-3). It consists of two Cesium vapor magnetometers separated horizontally by 1.5 meter (m), each recording at a sample rate of 10 Hertz (Hz). Each sensor is equipped with a depth sensor, and both are integrated with a single altimeter. The TVG is towed by a cable through which instrument data is transmitted to a laptop running MagLog software on a boat. The TVG was integrated with an RTK GPS.
- G-856 Magnetometer: The G-856 proton precession magnetometer was set up daily at the GPO site during data acquisition to monitor fluctuations in the earth's magnetic field, recording in units of nT. The instrument recorded the field intensity every 20 seconds, resulting in a diurnal drift curve that was applied to both the G-858 and G-882 data.
- Schonstedt GA-52 Cx: The GA-52 Cx Magnetic Locator (Schonstedt) is a hand-held gradiometer that detects the magnetic field of a ferromagnetic object. Instrument controls consist of an on/off sensitivity switch with five sensitivity settings and a volume control. It responds to the difference in the magnetic field between two sensors spaced about 0.51 m apart. The instrument provides audio detection signals that peak in frequency when the locator's tip is held directly over a ferrous object. The Schonstedt was used by qualified UXO personnel for anomaly avoidance, anomaly reacquisition, and for intrusive location clearance. Divers used the device encased in a water-proof housing when conducting underwater work in MRS-8.

- Topcon RTK GPS: HiperGa, Hiper+, and GR-3 models of Topcon RTK GPS were used at the site, and controlled with an Allegro CX field computer running Carlson SurvCE software. High-powered systems were used, transmitting at up to 35 Watts. The base station was set up daily on land (at any of several points listed in the surveyor report, Appendix D; See photos 02 and 21, Appendix H-1). When integrated with the G-858, the rover was mounted on a backpack worn by the operator (See photos 10 and 23, Appendix H-1). When integrated with the G-882 TVG, the rover was mounted on a metal frame centered on the stern of the boat, and the TVG's tow cable was mounted directly below the rover (See photo 03, Appendix H-3). NMEA 0183 data sentences were transmitted from the rover. For the terrestrial survey, GGA sentences were transmitted to the G-858 console. For the marine survey, both GGA and VTG sentences were transmitted by serial cable to the MagLog software on the laptop, and the rover was also connected to an Allegro CX mounted in front of the wheel of the boat, with waypoints uploaded to it to allow navigation over proposed transects.
- Leica Robotic Total Station (RTS): The RTS was used to reacquire marine magnetic anomalies in MRS-8 (See photo 09, Appendix H-3). It consists of a robotic base station with laser rangefinder that automatically tracks a rover prism. The base station was set up by resection using two points staked by ERT using RTK GPS at each setup location. The rover prism was mounted on a long pole carried by the diver, with a float on the top to keep the prism itself out of the water.
- Trimble GeoXH Global Positioning System: The GeoXH is a hand-held global positioning system (GPS) of sub-meter accuracy. It was used by the UXO team to lay out transects using waypoints and to locate grid corners for brush clearance operations.
- Sidescan sonar: A Klein System 3900 "fish" which collects data at a frequency of 900 kHz (See photo 04, Appendix H-3) was used to collect sidescan sonar data on the east side of Sandy Hook. The system was operated by Spencer Oceanographic Surveys, Inc. (SOS), a subcontractor of VRHabilis. VRHabilis was ERT's subcontractor for MRS-8.
- Odom Echotrac CVM, Transducer: Bathymetric data was acquired by Odom Echotrac CVM, Transducer: 200 kHz frequency with a 4 degree beam width, and logged by Hypack Software at a rate of 10 milliseconds. The system was also operated by SOS.

4.1.1.2 Terrestrial Geophysical Investigation Process

The terrestrial geophysical investigation in MRS-1 through MRS-7 took place in two phases, transects and grids. First, each MRS was investigated by a series of parallel transects placed over the entire MRS (Figure A-4-3 shows proposed transects). The rationale for location and spacing of the transects is presented in detail in Section 3.6.13.2 of the Work Plan, but also described briefly here. The CSM shows that the boundaries of MRS-1 through MRS-6 were defined to include an impact area of known location and diameter, and transects were designed conservatively in Visual Sample Plan (VSP) software with a goal of detecting impact areas rather than individual items. VSP determined a transect spacing able to detect areas of elevated anomaly density with a width of half the known impact area size within each MRS (based on the historical map in "Overview of Ordnance History – Fort Hancock, 1874-1919 [NPS, 1994]). Transect spacings of 82.5 to 188 feet were used in the MRSs, and a spacing of 30 feet was used in the B003 Area. The planned transects are shown in Figure A-4-3, while the actual transects collected in the field are shown in Appendix B-3. DGM data on the transects in all of these areas was acquired with the G-858 integrated with RTK GPS. The G-858 can detect ferrous objects to various depths depending on size. For example, a 37-mm round can be detected at a depth of approximately 0.4 m or less, or a 155-mm round can be detected at a depth of approximately 1.7 m or less (equation on Table 8-3, EM 1110-1-4009). Transects did not extend into the areas excluded by NPS, except in a few cases where data were collected along existing paths.

The CSM of MRS-7 was defined based on the explosion of the Livens Magazine. However, MRS-7 essentially lies within MRS-5 and was therefore evaluated in a similar manner using transect DGM in areas not excluded by NPS. To increase coverage in the NPS excluded areas of MRS-7 (approximately 83% of the MRS was excluded acreage), some meandering path DGM was also completed, and all anomalies on the meandering path were intrusively investigated, allowing for a qualitative assessment of the excluded area.

Anomalies mapped on transects were then analyzed by geostatistical mapping of anomaly density in VSP software. VSP identifies areas (called clusters) with anomaly density above a background density, as determined by spatial histogram (see Section 4.1.3.3 for a more detailed explanation). After USACE concurrence on cluster locations, grid locations were selected within the clusters. Grids of 100 ft x 100 ft in size were placed randomly by VSP within clusters. However, locations were often subject to change due to vegetation cutting restrictions imposed by NPS, due to cultural features, or due to the presence of standing water. Figures A-4-4 and A-4-5 show all clusters and grids within the MRSs.

DGM data in the grids was acquired with the goal of obtaining data along transects spaced two feet apart. In open areas such as the beach, 100 percent of each grid was covered. However, the inland grids were often covered with dense vegetation that could not be cut per NPS restrictions, and DGM coverage within the proposed grid boundary was occasionally less than 10%. In these cases coverage was often expanded into nearby open areas beyond the grid boundaries. In other cases additional grids were installed in open areas of clusters. In yet other cases "mag & dig" operations were carried out to increase coverage (mag & dig is using a Schonstedt to identify an anomaly and then manually excavating without further geophysical analysis). This process of expanding the areas to be investigated to achieve coverage goals is explained in more detail in Section 5.0.

All magnetic anomalies above a grid-specific threshold (as discussed in Section 4.1.3.1) were intrusively investigated. Although anomalies mapped on transects were intended for use in cluster analysis (see section 4.1.3.3) and not intended for intrusive investigation, some of these anomalies on transects were intrusively investigated as a means of increasing coverage.

The B003 Area of MRS-1, adjacent to the new proving battery, is an area of known MEC contamination thought to be a MEC disposal area based on the 1998 EE/CA investigation, and the investigation approach was slightly different from other areas. In order to determine the extent of this MEC contamination, in accordance with the approved Work Plan, tighter transects of 30 feet spacing were acquired at B003. No cluster analysis or grid installation was performed at B003 and all mapped anomalies were intrusively investigated.

In the two PAOIs, 9-Gun Battery and Kingman-Mills Battery, meandering path transects were completed to acquire data in accessible areas around the batteries. These PAOIs were outside of the MRSs and no cluster analysis or grid installation was performed; all mapped anomalies above the threshold were intrusively investigated.

4.1.1.3 Terrestrial Intrusive Investigation Process

Anomalies mapped using the G-858 within grids or on transects were added to dig sheets and coordinates were uploaded to RTK GPS and flagged using non-metallic pin flags by field geophysicists (anomaly selection is discussed in Section 4.1.3.1). For the reacquisition process, the G-858 was used by field geophysicists to reacquire each anomaly to refine its location following procedures outlined in the Work Plan (searching for peaks and troughs). New vertical gradient values and offset distances and directions were documented on the dig sheet for each anomaly. Occasionally anomalies were merged, or the signal could not be reacquired (i.e., ‘no finds’ potentially caused by an erroneous original signal that may have been the result of noise); these were documented.

UXO teams supervised by a UXO Technician III completed all excavations using shovels. Depth to contact, contact type, and other notes were added to the dig sheet. The UXO team excavated until the anomaly was encountered, or continued digging a minimum hole dimension of 18 inches in radius around the anomaly and 24 inches bgs if nothing was encountered. MPPEH was blown in place or taken to an approved disposal area for detonation, following procedures described in the Work Plan or specified in the ESP. MD was removed and stored in a secure location on site until disposal by a contractor at the end of the project. Cultural debris was either removed or left in place.

After intrusive work was completed in a grid, field geophysicists returned to each grid to complete anomaly resolution, or to check the area of 12 anomalies (as required by the Performance Work Statement) that were dug, to ensure that the vertical gradient signal dropped by 80% or more. All grids passed this test.

4.1.1.4 Marine Geophysical Investigation Process

For MRS-8, bathymetric and sidescan sonar surveys were carried out prior to data collection with the G-882 TVG, in order to refine the locations of the two transects in the water. The G-882 TVG can detect ferrous metal similar to the G-858, with sensitivity dropping with decreasing size of the metal object and with increasing distance below the sensor. For example, if the sensor is 0.5 m above the bottom, objects of approximately 50 mm diameter are detectable at the bottom surface, and objects of 90 mm diameter are detectable to 0.5 m below the bottom.

Transect 3 was planned to be acquired on the 6-feet bathymetric contour, and Transect 2 was planned to be in between the shoreline and Transect 3. Transect 1, the "beach transect," was acquired on land at the water's edge with the G-858 gradiometer at low tide. The marine data on Transects 2 and 3, located on the east side of Sandy Hook peninsula, were acquired with the G-882 TVG towed behind a boat after approval by USACE of data collected on the Instrument Verification Strip (IVS).

4.1.1.5 Marine Intrusive Investigation Process

After review and approval by USACE of the geophysical data acquired on MRS-8 Transects 1, 2, and 3, VRHabilis divers were approved to begin diving on anomalies. The divers operated from a dive trailer located on the beach on the east shore of Sandy Hook (see photo 10, Appendix H-3), and were connected to the trailer by umbilical hosing (air supply, communication, etc.).

Navigation to anomalies on Transect 1 on the beach was accomplished with RTK GPS. The G-858 was used to refine the reacquired location when the water was shallow enough to use it without risk of damage (See photo 7, Appendix H-3). Otherwise a waterproof Schonstedt was used by the diver to reacquire the anomaly and excavate it (See photos 8 and 11, Appendix H-3).

Navigation to marine anomalies was intended to be accomplished by dropping a heavy clump attached to a buoy from a boat navigated by RTK GPS, but during the course of fieldwork it was decided, with USACE concurrence, to use the RTS instead. Divers carried the prism pole with the prism out of the water, and communicated via radio with the dive supervisor in the dive trailer and RTS base operator (See photo 5, Appendix H-3). The base station was set up by resection using two points staked by ERT using RTK GPS at each setup location. The base station operator communicated by radio to the Dive Master, who instructed the diver to move a certain distance and direction until the prism was at the horizontal coordinates of the anomaly.

Upon arrival at the anomaly, divers performed an instrument-assisted search of the area using a Schonstedt in waterproof housing. Initially a 3-ft radius was searched. If nothing was found, a 6-feet radius was searched. Excavation of anomalies was accomplished by hand digging. A digital video camera was attached to the diver's helmet and video was recording during all dives, however not all video was successfully saved due to memory card limitations.

Divers investigated anomalies by instrument-assisted visual inspection of the area around each anomaly, followed by digging at any anomalies detected with the Schonstedt. If nothing was detected at a location, the search radius around the location was expanded. If nothing was found, the anomaly was marked as a "no contact."

4.1.2 <u>Geophysical Quality Control</u>

4.1.2.1 Geophysical Prove Out

The Geophysical Prove-out (GPO) Plan and GPO Report, which were finalized as standalone documents, are briefly described below.

The purpose of the GPO plan was to demonstrate and document the site-specific capabilities of the proposed survey systems, sensors, navigation equipment, data analysis, data management and associated equipment, and personnel to operate as an integrated system capable of meeting the project DQOs. ERT, USACE, and the NPS agreed that the previous GPO site, established during the EE/CA investigations in 1998, could be used for this GPO. Located within the Nike Radar Site in the central portion of the peninsula, the GPO site had geology, soil types, and topography similar to the areas that were the subject of the geophysical investigation.

The GPO was conducted by ERT at the proposed location on October 18-21, 2010. Sixteen seed items [industry standard objects (ISOs) or metal pipes] were placed in the subsurface and their locations were surveyed. Both the G-858 gradiometer and EM61 MK2A were used to collect data (with integrated RTK GPS), and their performance was evaluated. Threshold values of 24 nT/m for the G-858 and 22 mV stacked channel response for the EM61 were developed. As stated in the results of the GPO report, the EM61 outperformed the G-858. However, the use of the G-858 had been agreed upon with NPS because its footprint minimized potential damage to vegetation.

4.1.2.2 Daily Quality Control Tests

Quality control tests were conducted twice daily for each G-858 in the GPO area west of MRS-3, prior to ("AM") and immediately following ("PM") data collection. The G-858 was set up, turned on, and allowed to warm up for approximately 5 minutes, with the two sensors in the vertical orientation and the lower one approximately 6 inches above the ground. A "static background" test was conducted where the instrument recorded data for 3 minutes. A "cable shake" test was conducted where the instrument recorded data for one minute while the various cables were moved around to ensure proper connections. A "static spike" test was conducted where the instrument recorded data for 3 minutes, but with a steel rebar next to the lower sensor, causing the gradient to be in the 100 to 1000 nT/m range. Results of daily AM and PM Quality Control Tests are presented in Appendix B-2 (provided on CD only).

4.1.2.3 Marine Quality Control

Quality control for the DGM survey in the water in MRS-8 consisted of installation of an IVS, a line of repeated data, and verification of GPS rover accuracy.

The approximate location of the IVS was selected based on the location of shallow water near the Coast Guard Dock on the west side of the peninsula. Background data were collected with the TVG in a wide area on October 6, 2011. A "clean" area with no anomalies was selected for IVS installation, and USACE concurred. A map of the background data with the selected IVS location is shown in Appendix B-7.

Seven ISOs, or "seeds" were placed in the approved location on October 8, 2011. The water was approximately 20 feet deep at low tide. One small, one medium, and five large ISOs were used, and were placed at approximate depths ranging from 0 to 4 feet below the sea floor, and at a spacing of approximately 20 feet. Marker floats were installed at the ends of the seed line. The positions of the seeds were captured by RTK GPS based on floats connected to the seeds. Data were collected with the TVG on the IVS after installation of the seeds with multiple passes at various offsets being collected, but not all seed items were detected on any pass.

On October 10, 2011, it was decided to move the seed line to the east from its original location into somewhat shallower water (approximately 12 feet), and to increase the spacing of the seeds from 20 to 30 feet. Three of the original seeds could not be located and were abandoned.

Abandoned large ISOs were replaced with bundles of three medium ISOs taped together. On October 11, 2011, an RTS was used to capture seed locations, using a submersible prism pole of 15 feet length, rather than the RTK GPS, and a greater degree of accuracy was achieved (See photo 5, Appendix H-3). Data were collected with the TVG on the IVS after reinstallation of the seeds, and were submitted to USACE on October 12, 2011. Six of the seven seed items were detected (excluding the small ISO) on a pass where the sensors were essentially dragged on the bottom, and four of the items were detected with the sensors at altitudes (height above sea floor) of 2.3 m. Another pass was collected at approximately 1.65 m but it was offset to the southwest from the line, so only one item was detected. Maps showing the data from these passes are shown in Appendix B-7. Data could not be successfully acquired below 1.5 m sensor altitude due to the fact that the seeds were on a sloping surface and due to the presence of sand shoals both north and south of the IVS location, which prevented a straight line approach with the boat and also prevented the sensors from leveling at a stable altitude prior to encountering the seed line.

USACE concurred that the basic requirements of the IVS were fulfilled; the instrument was producing repeatable results and showing anomalies at seed locations. However, USACE requested additional testing to attempt to collect data at a sensor altitude of 1.5 m or less but not dragging on the bottom, as well as evaluation of sensitivity of the instrument to metallic objects to the sides of the sensors. Another attempt to collect data between 0 and 1.5 m above the bottom was unsuccessful; however, USACE gave approval to begin collecting data on the east coast of Sandy Hook on October 17, 2011.

4.1.2.4 Repeatability

Repeat lines were collected during the transect acquisition phase of the terrestrial geophysical fieldwork as well as in each individual grid with the G-858. Parts of transects were collected twice by the same operator on the same day in order to maximize the repeatability. In most grids at least one 100-ft long line was repeated. Results of repeat data are shown in Appendix B-2.

In MRS-8, a segment of Transect 3 that was collected with the G-882 TVG in the same location demonstrates repeatability of the data in the production area. The results are shown in Appendix B-8. The responses are generally similar, and any differences are likely caused by a difference in sensor altitude on the two passes.

4.1.2.5 Navigational Accuracy

RTK GPS was the primary means of navigation site wide. The base station was set up on monuments or survey nails daily with coordinates provided by a licensed surveyor, and the rover was always checked on a nearby point to ensure the coordinates were correct and that the signal was “fixed” at the highest accuracy. Equipment verification checklists are provided in Appendix B-1. However, during data collection in wooded areas, a “fixed” state was not always maintained due to tree canopy. Geophysical technicians monitored the GPS state on the G-858 console during data collection, and paused or stopped work if the signal deviated from fix. In some cases parts of grids were recollected in order to improve GPS data quality.

Handheld GPS units were used to navigate along transects. Because the exact position of the transects was determined more by existing vegetation that could not be cut than by evenly-spaced transects that would have been cut, the GPS quality did not need to be better than sub-meter accuracy.

The accuracy of the RTS, used only in MRS-8 for marine anomaly reacquisition, depended entirely on the accuracy of the RTK GPS, because resection points for the RTS were staked using the RTK GPS. Staked resection points were only used if the RTK GPS was in a fixed state. At one point the accuracy of the RTS was checked over a distance of approximately 2,275 feet, and an error of 1.9 feet east and 0 feet north was discovered. However, most anomalies were reacquired by divers less than 1,000 feet distant from the RTS base, so positional errors of less than 1 foot were achieved.

4.1.3 Geophysical Data Analysis

4.1.3.1 Processing and Anomaly Selection

Terrestrial G-858 Gradiometer Data

G-858 data were processed according to the Work Plan. The same process was applied to transects, meandering paths (in MRS-7), grids, and the B003 Area (in MRS-1). G-858 and G-856 magnetic data were downloaded from the instrument using Geometrics *MagMap2000®* software. Heading corrections caused by the offset of the sensor (in front of the operator) and the GPS rover antenna (worn on the operator's back) were made with this software. Dropouts (zero readings) are removed using the dropout filter. Dropouts were also removed from the G-856 data, followed by a smoothing filter. The G-856 data was used to make diurnal corrections to the G-858 data. The data was then exported to Geosoft .xyz format.

G-858 data was then imported to Geosoft Oasis Montaj® and processed using the following procedures:

- The data were converted from WGS84 Universal Transverse Mercator (UTM)18N, meter coordinates to NAD83, New Jersey State Plane coordinates in US survey feet;
- Latency corrections were performed based on instrument latency determined from the Six Line Test (performed during the GPO investigation) using the UCELATENCY application. Verification of proper latency corrections were made by reviewing maps for "chevron effects";
- Data were reviewed for completeness, across-track sampling, and velocity;
- The vertical magnetic gradient data and the analytic signal (AS) of the vertical gradient were gridded using the minimum curvature algorithm with a cell size of 0.5 feet;
- A series of color maps were produced from the gridded data; and
- Line paths were posted over the mapped data, and reviewed for coverage completeness.

The following procedures were followed for magnetic anomaly selection:

- The anomaly threshold value was selected that minimized the amount of anomaly picks without excluding items of interest. A unique threshold for each set of transects and each grid was based on 3X the site background value (Root Mean Square of noise). Anomalies along transects and in grids were automatically selected and added to a database for analysis or intrusive investigation based on the AS, using the Blakely method within UX-Process®; and

- The anomaly locations were reviewed and manually adjusted during QC using both the vertical magnetic gradient and calculated AS data. If the anomalies were related to known cultural features, they were deleted.
- USACE reviewed data and approved the anomalies selected for intrusive investigation by ERT using this process.

<u>Marine G-882 TVG Data</u>

GPS data and the TVG's magnetic data are automatically compiled during data collection into "Interpolator" files in MagLog. These files contain sensor positions calculated by MagLog from the layback geometry (distance between GPS rover and the two sensors, which was 10.74 m) and from the heading and velocity of the boat. These were added to Geosoft Oasis Montaj databases.

Data processing proceeded in accordance with the approved Work Plan (MRS-8 water addendum). All data collected when the RTK GPS was in an "autonomous" state (not "fixed" or "float") was eliminated, as well as all data where the sensor altitude was above 1.5 m. Drift-corrections were applied to the raw TVG data based on the G-856 data. Total field from each of the two sensors was processed individually (horizontal gradient was not used), and Analytic Signal was calculated using Geosoft Oasis Montaj (UX-Detect module).

For the TVG data (Transects 2, 3A, and 3B), anomaly selection was based on a 10 nT threshold, and 38 anomalies were selected. USACE added 3 additional QC anomalies to the dig sheet that were below 10 nT, for a total of 41 anomalies.

For Transect 1 on land, data were processed in the same way as the terrestrial data in MRS-1 through MRS-7. The threshold was 15 nT, and 11 anomalies were selected for intrusive investigation. USACE added 2 additional QC anomalies to the dig sheet that were below 15 nT, for a total of 13 anomalies.

4.1.3.2 Transects (Terrestrial)

Transects were laid out and vegetation was cut by UXO technicians in all 7 terrestrial MRSs in January and February of 2011. During the vegetation clearance, technicians performed an instrument assisted surface sweep of the transects, and discovered one MEC item on the surface in MRS-2 (see Section 5.1.2). Transects were laid out and vegetation was cut in the small portion of MRS-7 that was not excluded by NPS.

G-858 data were collected on the transects in January, February, and March, 2011. Data were submitted to USACE for review and approval prior to proceeding to Cluster Analysis (discussed in the next section). Transect characteristics are summarized in Table 4-1.

Table 4-1. Transect Summary by MRS and PAOI				
MRS/PAOI	**Nominal Spacing (ft)**	**Linear Feet Acquired**	**Threshold (nT/m)**	**Anomalies Mapped**
MRS-1	158	28,241	32	208
B003 Area of MRS-1	30	9,718	32	325
MRS-2	188	37,778	32	240
MRS-3	165	28,315	32	398
MRS-4	188	16,707	32	101
MRS-5	165	39,727	32	194
MRS-6	165	18,575	32	71
MRS-7	82.5	7,619*	32	47
PAOI: Kingman-Mills	none	6,354	250	51
PAOI: 9-Gun Battery	none	7,538	250	45

* Includes meandering path data in excluded area

For each MRS, Appendix B-3 presents maps of transects and anomalies, along with resulting clusters.

4.1.3.3 Cluster Analysis (Terrestrial)

The objective of cluster analysis is to focus the investigation on areas of high anomaly density assuming these represent areas of elevated MEC or MD contamination, interpreted to indicate impact areas. Cluster analysis was accomplished using VSP software, under the following menu:

- Sampling Goal > Find Target Areas and Analyze Survey Results (UXO) > Locate and mark target areas based on elevated anomaly density

For each MRS, coordinates of geophysical anomalies and transect locations (course over ground) were loaded into VSP. "Target Markers" (the centers of possible impact areas based on elevated anomaly density) were created by flagging areas significantly above the background anomaly density, and a "window" (circle moved along each transect in which anomalies are counted at a discrete interval) diameter equivalent to the nominal transect spacing (shown in Table 4-1). The background density was determined by examining a spatial histogram of the data and identifying the lowest density at which there was a significant drop in frequency from the lowest values (the various backround values were used with USACE concurrence). Delineation of areas with high anomaly density (clusters) was automatically generated from Target Markers assuming a "block" (square drawn around a target marker) width equivalent to the nominal transect spacing. Overlapping blocks defined the perimeters of clusters. An additional parameter in VSP was the minimum size of the target based on the Hazard Fragmentation Distance (HFD) of the smallest munition (grenade) from the Explosives Site Plan (ESP), provided in Section 6 of the Work Plan, which is 62 feet radius or 12,076 square feet. However, this was always smaller than the block size and was thus inconsequential.

In MRS-6 and MRS-7, one background value was used due to the presence of a single initial spike on the spatial histogram. For MRS-1 through MRS-5, more than one background value was used (based the spatial histogram), so that both low density and high density clusters were identified (e.g., in MRS-1 low density clusters had an anomaly density above 25 anomalies/acre, while high density clusters had a density above 100 anomalies/acre). Generally, the high density clusters were evaluated separately from the low density clusters in which they occurred. However, in MRS-5 high density clusters were used as a guide to place grids within low density clusters.

VSP files were sent to USACE for review and approval. Concurrently, the minimum area to investigate within each cluster was calculated using Unexploded Ordnance (UXO) Estimator (v2.2) software distributed by USACE. This software incorporates complex statistical algorithms (binomial probability mass functions) into a user-friendly interface geared toward munitions investigations, and it can be used to plan investigations and to analyze survey results including confidence levels in these results. "Confidence" is defined as the chance that the results obtained would not occur randomly. Ninety-five percent is a USACE requirement for use of this software.

The hypothesis of 5 UXO/acre (provided in the approved Work Plan) was used to develop a minimum area. The hypothesis is a UXO density against which to test an area by intrusive investigation, and it determines the minimum area that must be covered by DGM and in which all anomalies must be investigated. ERT proposed a number of grids approximating the minimum area recommended by UXO Estimator, and randomly placed grids within clusters. Often random grid locations were subject to revision due to vegetation cutting restrictions set by NPS, due to cultural features, or due to the presence of standing water. With regard to cultural features, all final grid locations were approved by NPS.

In several cases (e.g., MRS-1, Cluster 6), an additional grid was added after it was discovered that adequate coverage could not be obtained in the original grids. For similar reasons, in some cases, anomalies were dug on the original transects (discussed in Section 4.1.3.2) to increase coverage within clusters (discussed more fully in Section 5.1).

<u>MRS-1 Cluster Analysis</u>

Cluster analysis of transect anomalies in MRS-1 was completed and VSP files were submitted to USACE on March 3, 2011, along with recommended grid locations. A summary of the clusters in MRS-1 is shown in Table 4-2. The clusters are shown in Figure A-4-4, as well as in Appendix B-3.

No cluster analysis was necessary in the B003 Area because all anomalies on the closely-spaced transects were intrusively investigated.

Table 4-2. Clusters in MRS-1

Cluster No.	Cluster Area (acres)	Background (anomalies/ac)	Min. Area at 5 UXO/Acre (acres)	Approved Number of Grids	Actual Grids in Cluster
C1	1.79	100	0.466	1	G1-1
C3	1.30	25	0.429	1	G1-7
C4	0.73	100	0.347	1	G1-6
C5	0.57	100	0.309	1	G1-8
C6	49.04	25	0.594	3	G1-5 G1-14 G1-17 G1-18
C8	0.66	100	0.332	1	G1-11
C11	1.14	100	0.412	1	G1-15
C12	0.68	100	0.336	1	G1-16
C13	3.22	100	0.518	3	G1-2 G1-3 G1-4
C14	5.44	100	0.549	2	G1-9 G1-10
C15	4.21	100	0.535	2	G1-12 G1-13

<u>MRS-2 Cluster Analysis</u>

Cluster analysis of transect anomalies in MRS-2 was completed and VSP files were submitted to USACE on February 18, and revised on February 23, 2011, along with recommended grid locations. A summary of the clusters in MRS-2 is shown in Table 4-3.

Table 4-3. Clusters in MRS-2

Cluster No.	Cluster Area (acres)	Background (anomalies/ac)	Min. Area at 5 UXO/Acre (acres)	Approved Number of Grids	Actual Grids in Cluster
C1	60.86	25	0.595	3	G2-1 G2-4 G2-9 G2-12

Table 4-3. Clusters in MRS-2

Cluster No.	Cluster Area (acres)	Background (anomalies/ac)	Min. Area at 5 UXO/Acre (acres)	Approved Number of Grids	Actual Grids in Cluster
C2	1.55	25	0.450	1	G2-6
C1D	2.85	150	0.509	2	G2-2 G2-3
C2D	4.32	150	0.537	3	G2-5 G2-7 G2-8
C3D	1.31	150	0.430	1	G2-10
C4D	1.43	150	0.440	1	G2-11
C5D	1.20	*Anomalies in Cluster 5D caused by fence around water treatment plant. No grids installed.*			

<u>MRS-3 Cluster Analysis</u>

Cluster analysis of transect anomalies in MRS-3 was completed and VSP files were submitted to USACE on February 23, 2011, along with recommended grid locations. A summary of the clusters in MRS-3 is shown in Table 4-4.

Table 4-4. Clusters in MRS-3

Cluster No.	Cluster Area (acres)	Background (anomalies/ac)	Min. Area at 5 UXO/Acre (acres)	Approved Number of Grids	Actual Grids in Cluster
C1	0.63	300	0.324	1	G3-4
C2	0.92	300	0.382	1	G3-6
C3	5.16	300	0.546	3	G3-8 G3-9 G3-10
C4	0.62	100	0.322	1	G3-3
C11	45.91	100	0.593	3	G3-2 G3-5 G3-7 G3-11
C2A	1.07	100	0.403	1	G3-1

MRS-4 Cluster Analysis

Cluster analysis of transect anomalies in MRS-4 was completed and VSP files were submitted to USACE on March 1, and revised on March 3, 2011, along with recommended grid locations. A summary of the clusters in MRS-4 is shown in Table 4-5.

Table 4-5. Clusters in MRS-4

Cluster No.	Cluster Area (acres)	Background (anomalies/ac)	Min. Area at 5 UXO/Acre (acres)	Approved Number of Grids	Actual Grids in Cluster
C1	1.92	*Cluster 1 in NPS excluded area. No grids installed.*			
C4A/C2	5.91	20/100	0.553	3	G4-3 G4-5 G4-7
C8A/C4	2.42	20/100	0.495	2	G4-9 G4-10
C5	5.15	100	0.546	2	G4-1 G4-6
C2A	18.84	20	0.584	3	G4-8 G4-11 G4-12 G4-14
C3A	1.39	20	0.437	1	G4-13
C5A	0.98	20	0.391	1	G4-2
C6A	1.65	20	0.457	1	G4-4

MRS-5 Cluster Analysis

Cluster analysis of transect anomalies in MRS-5 was completed and VSP files were submitted to USACE on March 1, and revised on March 3, 2011, along with recommended grid locations. A summary of the clusters in MRS-5 is shown in Table 4-6.

Note that in this MRS, high density clusters (60 anomalies/acre) were generated, but due to constraints on grid placement as a result of large excluded areas and many cultural features such as the Nike Missile Launch Area, the high density clusters were used as a guide for placement of grids within the low density clusters. As discussed in Section 5.0, the high density clusters were not evaluated individually for MEC density as they were in other MRSs.

Table 4-6. Clusters in MRS-5

Cluster No.	Cluster Area (acres)	Background (anomalies/ac)	Min. Area at 5 UXO/Acre (acres)	Approved Number of Grids	Actual Grids in Cluster
C1	2.41	*Most of Cluster 1 is parking lot or NPS excluded area. No grids installed.*			
C2	10.73	20	0.573	2	G5-1 G5-2
C3	0.87	20	0.374	1	G5-3
C4	0.82	20	0.365	1	G5-4
C11	2.78	20	0.507	1	G5-12
C18	2.97	20	0.512	2	G5-11 G5-13
C19	7.34	20	0.561	3	G5-5 G5-6 G5-7
C20	7.00	20	0.559	3	G5-8 G5-9 G5-10
C21	25.68	20	0.588	7	G5-14 G5-15 G5-16 G5-17 G5-18 G5-19 G5-20

<u>MRS-6 Cluster Analysis</u>

Cluster analysis of transect anomalies in MRS-6 was completed and VSP files were submitted to USACE on February 18, 2011, along with recommended grid locations. A summary of the clusters in MRS-6 is shown in Table 4-7.

Table 4-7. Clusters in MRS-6

Cluster No.	Cluster Area (acres)	Background (anomalies/ac)	Min. Area at 5 UXO/Acre (acres)	Approved Number of Grids	Actual Grids in Cluster
C1	1.33	33	0.431	1	G6-1
C2	0.91	33	0.380	1	G6-2
C3	0.91	33	0.380	1	G6-3
C4	2.98	33	0.512	2	G6-4 G6-5
C7	0.60	33	0.317	1	G6-9
C8	9.27	33	0.569	3	G6-6 G6-7 G6-8*

* G6-8 had dimensions of 200 x 40 feet in order to fit it in the proposed area.

<u>MRS-7 Cluster Analysis</u>

Cluster analysis of transect anomalies in MRS-7 was completed and VSP files were submitted to USACE on April 19, 2011 along with recommended grid locations. The relatively few clusters correlates to the number of anomalies found. A summary of the clusters in MRS-7 is shown in Table 4-8.

The meandering path data collected in the NPS excluded area of MRS-7 was used for cluster analysis. All anomalies on the meandering path were intrusively investigated. However, no grids could be installed in the NPS excluded area.

Table 4-8. Clusters in MRS-7

Cluster No.	Cluster Area (acres)	Background (anomalies/ac)	Min. Area at 5 UXO/Acre (acres)	Approved Number of Grids	Actual Grids in Cluster
C1	1.66	40	0.458	2	G7-1 G7-2
C2	0.31	40	0.215	1	G7-3
C3	0.67	*Cluster 3 in NPS excluded area. No grids installed.*			

4.1.3.4 Grids (Terrestrial)

Grid corners were staked out by licensed surveyors or by ERT using RTK GPS. Due to restrictions on vegetation removal imposed by NPS, achieving DGM coverage goals within grids was challenging. Generally, approximately 100% coverage was accomplished on grids that were at or near the beach or otherwise in open areas free of vegetation. However, coverage was limited in grids with significant vegetation. As a means of increasing coverage, data collection was expanded beyond the grid boundary into adjacent open areas.

In areas where MEC or MD were found and coverage within a grid was low, the mag & dig technique was employed to cover vegetated areas within the grid. UXO technicians used Schonstedts to search for anomalies in the dense vegetation and then immediately manually excavated them, leaving a flag at the location. Coordinates of flags were later captured by geophysicists using the RTK GPS.

For each grid, two maps of DGM data, one providing vertical gradient (nT/m) and one providing analytic signal (nT) data, are presented in Appendix B-5. Maps of the B003 Area, PAOI 9-Gun Battery, and PAOI Kingman-Mills Battery providing vertical gradient and analytic signal are also included.

Summary information for each grid, on an MRS basis, is presented in the tables below.

<u>MRS-1 Grids</u>

A summary of grids in MRS-1 is shown in Table 4-9.

Table 4-9. Grids in MRS-1

Grid	Cluster	DGM Acres	Threshold (nT/m)	DGM Anomalies	Mag & Dig Acres	Mag & Dig Anomalies
G1-1	C1	0.22	40.0	62	NA	NA
G1-2	C13	0.07	50.0	5	NA	NA
G1-3	C13	0.06	40.0	14	NA	NA
G1-4	C13	0.38	40.0	102	NA	NA
G1-5	C6	0.02	170.0	33	NA	NA
G1-6	C4	0.07	25.0	11	0.16	6
G1-7	C3	0.22	90.0	93	NA	NA
G1-8	C5	0.10	45.0	54	NA	NA
G1-9	C14	0.16	35.0	140	0.07	18
G1-10	C14	0.20	168.0	79	NA	NA
G1-11	C8	0.14	270.0	95	NA	NA
G1-12	C15	0.22	80.0	173	NA	NA
G1-13	C15	0.23	80.0	145	NA	NA
G1-14	C6	0.21	200.0	89	NA	NA
G1-15	C11	0.12	160.0	38	0.11	20
G1-16	C12	0.10	30.0	86	NA	NA
G1-17	C6	0.23	80.0	34	NA	NA
G1-18	C6	0.23	80.0	13	NA	NA
Total		**3.00**		**1266**	**0.34**	**44**

<u>MRS-2 Grids</u>

A summary of grids in MRS-2 is shown in Table 4-10.

Table 4-10. Grids in MRS-2

Grid	Cluster	DGM Acres	Threshold (nT/m)	DGM Anomalies	Mag &Dig Acres	Mag& Dig Anomalies
G2-1	C1	0.11	45.0	32	NA	NA
G2-2	C1D	0.20	45.0	91	NA	NA
G2-3	C1D	0.20	29.0	118	NA	NA
G2-4	C1	0.20	61.0	66	NA	NA
G2-5	C2D	0.07	45.0	32	0.16	7
G2-6	C2	0.23	15.0	13	NA	NA
G2-7	C2D	0.10	45.0	53	0.13	4
G2-8	C2D	0.08	50.0	19	NA	NA
G2-9	C1	0.11	50.0	53	NA	NA
G2-10	C3D	0.08	55.0	45	0.15	19
G2-11	C4D	0.16	190.0	86	0.07	11
G2-12	C1	0.23	20.0	39	NA	NA
Total		**1.78**		**647**	**0.51**	**41**

<u>MRS-3 Grids</u>

A summary of grids in MRS-3 is shown in Table 4-11.

Table 4-11. Grids in MRS-3

Grid	Cluster	DGM Acres	Threshold (nT/m)	DGM Anomalies	Mag &Dig Acres	Mag& Dig Anomalies
G3-1	C2A	0.06	135.0	32	0.17	12
G3-2	C11	0.12	60.0	34	NA	NA
G3-3	C4	0.13	20.0	49	NA	NA
G3-4	C1	0.08	50.0	33	NA	NA
G3-5	C11	0.21	130.0	41	NA	NA
G3-6	C2	0.10	80.0	71	0.13	15
G3-7	C11	0.20	60.0	31	NA	NA
G3-8	C3	0.13	60.0	75	NA	NA
G3-9	C3	0.31	85.0	117	NA	NA
G3-10	C3	0.20	90.0	62	NA	NA
G3-11	C11	0.23	26.0	81	NA	NA
Total		**1.76**		**626**	**0.30**	**27**

<u>MRS-4 Grids</u>

A summary of grids in MRS-4 is shown in Table 4-12.

Table 4-12. Grids in MRS-4

Grid	Cluster	DGM Acres	Threshold (nT/m)	DGM Anomalies	Mag &Dig Acres	Mag& Dig Anomalies
G4-1	C5	0.26	50.0	118	NA	NA
G4-2	C5A	0.13	18.0	27	0.10	12
G4-3	C4A/C2	0.06	220.0	25	NA	NA
G4-4	C6A	0.20	32.5	47	NA	NA
G4-5	C4A/C2	0.10	11.6	6	NA	NA
G4-6	C5	0.23	40.0	54	NA	NA
G4-7	C4A/C4	0.05	29.0	24	NA	NA
G4-8	C2A	0.10	40.0	23	NA	NA
G4-9	C8A/C4	0.08	20.0	39	0.16	17
G4-10	C8A/C4	0.18	22.5	27	NA	NA
G4-11	C2A	0.07	45.0	14	NA	NA
G4-12	C2A	0.10	55.0	25	NA	NA
G4-13	C3A	0.11	22.5	20	NA	NA
G4-14	C2A	0.17	23.5	25	NA	NA
Total		**1.84**		**474**	**0.26**	**29**

MRS-5 Grids

A summary of grids in MRS-5 is shown in Table 4-13.

Table 4-13. Grids in MRS-5

Grid	Cluster	DGM Acres	Threshold (nT/m)	DGM Anomalies	Mag &Dig Acres	Mag& Dig Anomalies
G5-1	C2	0.38	45.0	49	NA	NA
G5-2	C2	0.25	29.0	57	NA	NA
G5-3	C3	0.24	19.0	15*	0.23	6
G5-4	C4	0.17	14.5	4	NA	NA
G5-5	C19	0.28	60.0	92	NA	NA
G5-6	C19	0.22	290.0	47	NA	NA
G5-7	C19	0.17	310.0	23	NA	NA
G5-8	C20	0.24	15.5	32	NA	NA
G5-9	C20	0.22	19.0	16	NA	NA
G5-10	C20	0.18	40.0	79	NA	NA
G5-11	C18	0.23	22.5	27	NA	NA
G5-12	C11	0.13	50.5	27	NA	NA
G5-13	C18	0.24	21.0	9	NA	NA
G5-14	C21	0.14	25.0	29	NA	NA
G5-15	C21	0.26	130.0	28	NA	NA
G5-16	C21	0.30	45.0	56	NA	NA
G5-17	C21	0.27	145.0	67	NA	NA
G5-18	C21	0.03	20.0	26	NA	NA
G5-19	C21	0.18	50.0	35	NA	NA
G5-20	C21	0.27	110.0	74	NA	NA
Total		**4.40**		**777**	**0.23**	**6**

* Due to surf washing sand into G5-3, after G-858 data collection but before reacquisition and digging, it was necessary to perform mag & dig operations on this grid only.

MRS-6 Grids

A summary of grids in MRS-6 is shown in Table 4-14. No mag & dig activities were performed in any of these grids.

Table 4-14. Grids in MRS-6

Grid	Cluster	DGM Acres	Threshold (nT/m)	DGM Anomalies
G6-1	C1	0.23	100.0	61
G6-2	C2	0.23	14.5	24
G6-3	C3	0.23	170.0	106
G6-4	C4	0.22	45.0	55
G6-5	C4	0.22	65.0	65
G6-6	C8	0.21	310.0	43
G6-7	C8	0.22	95.0	61
G6-8	C8	0.19	145.0	30
G6-9	C7	0.23	22.5	40
Total		**1.99**		**485**

MRS-7 Grids

A summary of grids in MRS-7 is shown in Table 4-15. No mag & dig activities were performed in any of these grids. The relatively small number of grids correlates to the number and size of the clusters.

Table 4-15. Grids in MRS-7

Grid	Cluster	DGM Acres	Threshold (nT/m)	DGM Anomalies
G7-1	C1	0.09	45.0	9
G7-2	C1	0.10	22.5	20
G7-3	C2	0.08	21.0	15
Total		**0.27**		**44**

4.1.3.5 Marine Transects

Bathymetric and sidescan sonar surveys were carried out by SOS on October 7, 2011, and bathymetric data was provided to ERT on October 12, 2011. Bathymetric data was used to refine the locations of the two transects in the water (Transects 2 and 3). Transect 3 was planned to be acquired on the 6-feet bathymetric contour, and Transect 2 was planned to be in between the shoreline and Transect 3. Sidescan sonar data are provided with the bathymetric data in Appendix B-9.

Transect 1 was acquired on land at the water's edge with the G-858 gradiometer. The transect was collected between 6:25 am and 8:05 am, at a low tide which occurred at 6:59 am on October 18, 2011. Data were submitted to USACE for review the same day.

The marine data on Transects 2 and 3 were also acquired on October 18, 2011. GPS quality, sensor readings, signal strength, and instrument depth and altitude (distance above sea floor) were monitored in real time as well as recorded. A DQO was to maintain a sensor altitude of 1.5 m or less throughout the survey area. In shallow areas of less than 1.5 m water depth (Transect 2), the boat speed was maintained in order to keep the instrument at the surface. The boat speed was lowered for acquisition on Transect 3, in order to let the sensors drop. Due to difficulty maintaining an acceptable sensor altitude on the first run of Transect 3, the transect was immediately re-run. The two transects were designated 3A and 3B. Data were submitted to USACE for review on October 20, 2011.

The coverage goal for the two marine transects stated in the Work Plan (MRS-8 water addendum, ERT 2011) was 6.7 acres, or approximately 8.4 linear miles of transect at 2 m width, and this was exceeded. Approximately 49,600 linear feet or 9.4 miles of usable data were acquired, covering approximately 7.47 acres in the water. Transect 1, on land, was 21,420 feet (4.0 miles) long, and at 1 m width, covered 1.61 acres.

Dig sheets of the intrusive investigation of the anomalies for Transects 1, 2, 3A, and 3B in MRS-8 are provided in Appendix C-3.

4.2 Munitions Constituents Characterization

Environmental sampling of soil, surface water, sediment, and groundwater, was completed to characterize MC. In accordance with the Work Plan and DQOs, sampling had specific objectives and was not always associated with an individual MRS. Figure A-4-6 shows all of the sample locations discussed below.

4.2.1 Soil Samples

The Work Plan specified that random discrete and biased soil samples be collected. Random discrete soil samples were collected only at MRS-7 locations. All random soil samples were collected at depths of 0-6 inches bgs.

The Work Plan required that biased samples associated with MEC items be collected at locations where there was visible evidence of energetic material (e.g., munitions items which are breached) or in areas of significant MD, where at least 50% of the munitions could be identified by UXO Technicians. However, no evidence of energetics was found and none of these biased soil samples were collected.

Samples associated with MEC blow-in-place (BIP) activities were collected using incremental sampling (IS) methodology. BIP samples were collected to determine if MC was released during detonation of found items.

A summary of the soil sampling conducted, including sample locations, numbers, and the type of analysis, is presented in Table 4-16**.**

4.2.1.1 IS (BIP)

All IS samples were associated with MEC blow-in-place (BIP) activities. Post-detonation soil samples could only be collected for six of the seven MEC finds. Due to safety concerns related to stability of the MEC items, only one of those six also contained a pre-BIP sample.

The post-detonation (post-BIP) soil samples were collected between 0-6 inches bgs using IS as follows: a 30-ft by 30-ft grid was laid out to encompass the area to be investigated (i.e., the sampling unit) by collecting 30 evenly spaced soil increments of approximately equal weight from each grid. Each of the 30 increments collected was deposited directly into a large plastic bag to form one 2 kilogram (kg) composited sample for submittal to the laboratory. Grinding was conducted for explosives analysis using the ring and puck mill. Grinding was also conducted for metals analysis, using mortar and pestle (non-metallic) methods. All post-BIP samples were analyzed for explosives and metals using USEPA Method 8330B and USEPA Method 6010B, respectively.

In MRS-1, post-BIP sampling was performed for three MEC finds; one of these also included a pre-BIP sample. In Grid 1-16, one post-BIP IS sample was collected on March 25, 2011. In Grid 1-10, one post-BIP IS sample was collected on March 30, 2011. In Grid 1-6, one pre-BIP IS sample was collected November 10, 2011, and the associated post-BIP sample was collected on November 11, 2011.

In MRS-2, one post-BIP IS sample was collected on January 24, 2011. The MEC item was found along a transect and was not associated with a specific grid.

In MRS-5, post-BIP sampling was performed for two MEC finds. In Grid 5-11, one post-BIP IS sample was collected on December 14, 2011, and in Grid 5-16, one post-BIP IS sample was collected on December 15, 2011.

4.2.1.2 Random Discrete (MRS-7)

Based on concerns expressed by NJDEP, and to ensure that the Livens Discovery Area (MRS-7) was thoroughly characterized, a random surface soil sampling approach (discrete grab samples) was developed through VSP to support a statistical comparison to applicable screening standards for the analytes (metals and explosives). VSP recommended 21 randomly located samples as shown in Figure A-4-6.

A total of 21 random samples were collected on March 30, 2011, within MRS-7. These samples were located primarily in NPS-excluded areas of MRS-7 and were therefore collected under the supervision of NPS personnel. These samples were collected with disposable scoops at depths of 0-6 inches bgs, and were analyzed for metals and explosives by SW-846 Method 6010B/7470A and SW-846 Method 8330B, respectively.

4.2.2 <u>Surface Water and Sediment Samples</u>

Surface water and sediment samples were collected in accordance with the procedures in the approved Work Plan. Surface water and co-located sediment samples were collected from Nike Pond (located within MRS-5, and a photo is shown in Appendix H-2) in three areas, distributed roughly equidistant around the perimeter of the pond (approximately northwest, northeast, and southern perimeter), to evaluate surface run-off (Figure A-4-6). Each of the three Nike Pond locations contained a surface water sample and a co-located sediment sample (0-6 inches bgs).

As requested by NJDEP, each co-located sediment sample also had a subsurface sample collected approximately 6-12 inches deep (i.e., directly below the initial sediment sample). The surface water samples were collected using location-specific dedicated bottle samplers and the sediments were collected using a hand auger. The hand auger was decontaminated between samples and an equipment rinsate sample was collected. These samples were analyzed for metals and explosives by SW-846 Method 6010B/7470A and SW-846 Method 8330B, respectively. A summary of the surface water and sediment sampling conducted, including sample locations, numbers, and the type of analysis, is presented in Table 4-17.

4.2.3 <u>Groundwater Samples</u>

In accordance with the Work Plan, groundwater samples were to be collected from six existing monitoring wells located at various areas throughout Fort Hancock. Of these wells, only two were directly within an MRS. However, the intent was to obtain as much groundwater data from existing sources to assess overall groundwater conditions. Figure A-4-6 shows the locations of the six wells.

One of the six wells (GW 17) was dry and could not be sampled. One of the wells was the potable drinking water well that serves the entire peninsula; that well (Pumphouse, DW 01) was sampled from a tank spigot prior to treatment (i.e., raw water).

Groundwater samples were collected in general accordance with the procedures in the approved Work Plan. Prior to sampling, each existing well was measured for total depth and depth to groundwater and well volumes were calculated. Due to small volumes of water present, to ensure representativeness of the sample, the equivalent of three times the calculated well volume was purged from the well via location-specific dedicated/disposable hand bailers (based on site logistics, it was not practical to use a pump for some of these wells). Samples were then collected via location-specific hand bailers. An exception was well GW 2E, which could only be purged approximately two volumes.

All wells were sampled on December 20, 2011. All groundwater samples were analyzed for metals and explosives by SW-846 Method 6010B/7470A and SW-846 Method 8330B, respectively. A summary of the groundwater sampling plan, including well information, sample numbers, and the type of analysis, is presented in Table 4-18.

MW 1 is just outside of the 9-Gun Battery PAOI and MRS-1. GW 17 is within MRS-1, near New Proving Battery Firing Point. However, this well was dry each time it was measured during the course of the field effort and could not be sampled. Well S909 is approximately 400 feet west of the northern end of MRS-1. GW 11 is within MRS-4. GW 2E is within MRS-5, just outside of MRS-7. Photos of each of these wells are shown in Appendix H-2.

DW 01 is the potable drinking water well that serves the entire peninsula. It is also known as the pumphouse well and was sampled from a tank spigot prior to treatment (i.e., raw water). The water from the raw water tank is sent to a sand filter prior to consumption. Although this well draws groundwater from a confined aquifer approximately 880 feet deep, and does not reflect the groundwater in the other sampled wells, it was sampled to accommodate an NPS request.

Table 4-16. Soil Sampling Summary

Media	Location	Sample Type	Sample Name	Analytical Parameter	Field Samples\1	Notes
Soil	MRS-1	IS (BIP)	FHRI-01-SO-01 FHRI-01-SO-02 FHRI-01-SO-03 FHRI-01-SO-04	Metals, Explosives	4	FHRI-01-SO-03 and FHRI-01-SO-04 are a pre and post-BIP set. All others were post-BIP only (due to safety issues)
	MRS-2	IS (BIP)	FHRI-01-SO-02	Metals, Explosives	1	Post-BIP
	MRS-5	IS (BIP)	FHRI-05-SO-01 FHRI-05-SO-02	Metals, Explosives	2	Post-BIP samples
	MRS-7	Random Discrete	FHRI-07-01 through FHRI-07-21	Metals, Explosives, pH, TOC	21	Not associated with MEC

Notes:

\1 – Does not include QA/QC samples
Metals and explosives by SW-846 Method 6010B/7470A and SW-846 Method 8330B, respectively
BIP – Blow-in-place
IS –Incremental Sample
TOC – Total Organic Carbon

Table 4-17. Sediment and Surface Water Sampling Summary						
Media	**Location**	**Sample Type**	**Sample Name**	**Analytical Parameter**	**Field Samples[\1]**	**Notes**
Surface Water	MRS-5 (Nike Pond)	Discrete	FHRI-05-SW-01 FHRI-05-SW-02 FHRI-05-SW-03	Metals, Explosives	3	3 samples placed equidistant around the pond's edge
Sediment	MRS-5 (Nike Pond)	Discrete	FHRI-05-SD-01 FHRI-05-SD-01(06) FHRI-05-SD-02 FHRI-05-SD-02(06) FHRI-05-SD-03 FHRI-05-SD-03(06)	Metals, Explosives	6	Co-located with the 3 surface waters above, but two depths, 0-6 inches bgs and 6-12 inches bgs

Notes:

\1 – Does not include QA/QC samples
All samples were collected December 15 and 16, 2011.
Metals and explosives by SW-846 Method 6010B/7470A and SW-846 Method 8330B, respectively.

Table 4-18. Groundwater Well Sampling Summary

Media	Well Name	Sample Name	Location	Total Well Depth (ft)	Depth to Groundwater (ft below TOC)	Analytical Parameters	Notes
Groundwater	MW1	FHRI-MW1	Near 9-Gun Battery	15.7	7.92	Metals, Explosives	Outside of 9-Gun Battery PAOI and MRS-1
	GW17	NA	MRS-1	6.8	DRY	NA	Near New Proving Battery Firing Point. Could not be sampled.
	S909	FHRI-S909	West of MRS-1	17.45	5.1	Metals, Explosives	Outside of MRS-1 (approx. 400 ft west)
	GW11	FHRI-GW11	MRS-4	17.87	7.48	Metals, Explosives	Within MRS-4
	GW2E	FHRI-GW2E	MRS-5	14.78	3.66	Metals, Explosives	Within MRS-5
	Pumphouse (DW01)	FHRI-DW01	West of MRS-2	397	NA	Metals, Explosives	Outside of MRS-2 (approx. 1,800 ft west). Potable water, but sample collected was raw water, prior to treatment

Notes:

All wells were sampled on December 20, 2011
Metals and explosives by SW-846 Method 6010B/7470A and SW-846 Method 8330B, respectively
MW – Monitoring Well
GW – Groundwater Well
TOC – Top of Casing

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5.0 REMEDIAL INVESTIGATION RESULTS AND REVISED CSM

Section 5.0 presents the results of the intrusive investigation and environmental sampling activities. Section 5.1 addresses the MEC/MD intrusive investigation findings and 5.2 provides the analysis of those findings. Section 5.3 presents the MC sampling findings (including a Data Quality Assessment). The analysis of MEC/MD and MC findings forms the basis of the updated/revised CSMs presented in Section 5.4. Section 5.5 presents a discussion of uncertainties associated with DGM and MEC/MD findings.

5.1 MEC Intrusive Investigation Findings

This section provides the detail of the RI findings on an MRS level. These are summarized in individual tables and the discussions below. The DGM anomalies in the tables are the anomalies intrusively investigated in that MRS. Mag & dig operations (using a Schonstedt to identify an anomaly and then manually excavating without further geophysical analysis) were sometimes carried out to increase coverage. MEC and MD items found are shown per grid, with descriptions in the tables. Figures A-5-1 and A-5-2 show all grid locations within the MRSs, and whether the grids contained MEC, MD, or no MEC/MD, with each MEC find described and called out on the figures. In addition, Appendix B-4 provides MRS level figures graphically showing grid DGM coverage.

Unless otherwise indicated in the discussions below, the applicable DQOs described in Section 3.0 were met.

5.1.1 MRS-1

A summary of the results of the intrusive investigations in all MRS-1 grids is shown in Table 5-1, and grid locations are shown in Figure A-5-1. The dig sheets of these grids, showing the results of the intrusive investigation and specific findings at each anomaly, are provided in Appendix C-2. Photos of MEC and some MD items found within this MRS are shown in Appendix C-4.

Table 5-1. Intrusive Investigation of MRS-1

Grid	DGM Anomalies	Mag & Dig Anomalies	MEC Found	MD Found	MEC/MD Description
G1-1	62	NA	0	0	
G1-2	5	NA	0	0	
G1-3	14	NA	0	0	
G1-4	102	NA	0	1	Miscellaneous MD scrap
G1-5	33	NA	0	0	
G1-6	11	6	1	0	Anomaly #7 (MEC), 75mm projectile, fuzed and fired. BIP'd 11/11/11
G1-7	93	NA	0	0	
G1-8	54	NA	0	0	
G1-9	140	18	0	0	
G1-10	79	NA	1	0	Anomaly #47 (MEC), MK 1, 1-lb, 1.44-in diameter, 3-in length. BIP'd 3/30/11

Table 5-1. Intrusive Investigation of MRS-1					
Grid	**DGM Anomalies**	**Mag & Dig Anomalies**	**MEC Found**	**MD Found**	**MEC/MD Description**
G1-11	95	NA	0	0	
G1-12	173	NA	0	0	
G1-13	145	NA	0	0	
G1-14	89	NA	0	3	10" AP proof round (MD), MD frag, and MD scrap
G1-15	38	20	0	6	Miscellaneous MD frag and scrap
G1-16	86	NA	1	13	Anomaly #64 (MEC), 3.5-in diameter, 9-in length with base fuze. BIP'd 3/25/11 by EOD from NWS Earle. Anomalies #48 and #50 (MD), five 6-inch projectiles (empty), two 4.7-inch projectiles (empty), two 3.5-inch projectiles (empty), four 75-mm projectiles (empty)
G1-17	34	NA	0	0	
G1-18	13	NA	0	0	
Totals	**1,266**	**44**	**3**	**23**	

<u>B003 Area</u>

A total of 325 anomalies in the B003 Area of MRS-1 were also excavated. A total of 16 anomalies contained MD (mostly fragments). No MEC was found. The dig sheet for this area, showing specific findings at each anomaly, is shown in Appendix C-2.

5.1.2 <u>MRS-2</u>

A summary of the results of the intrusive investigations in all MRS-2 grids (and along the original transects) is shown in Table 5-2, and grid locations are shown in Figure A-5-1. The dig sheets of these grids and transects, showing specific findings at each anomaly, are provided in Appendix C-2. Photos of MEC found within this MRS are shown in Appendix C-4.

Table 5-2. Intrusive Investigation of MRS-2					
Grid	**DGM Anomalies**	**Mag & Dig Anomalies**	**MEC Found**	**MD Found**	**MEC/MD Description**
G2-1	32	NA	0	0	
G2-2	91	NA	0	2	MD frag (rotating band) and MD frag 75mm
G2-3	118	NA	0	0	
G2-4	66	NA	0	0	
G2-5	32	7	0	1	Miscellaneous MD scrap
G2-6	13	NA	0	0	
G2-7	53	4	0	2	Miscellaneous MD frag (both)
G2-8	19	NA	0	0	
G2-9	53	NA	0	0	
G2-10	45	19	0	5	Miscellaneous MD frag (all anomalies)
G2-11	86	11	0	0	
G2-12	39	NA	0	0	
Surface	NA	NA	1	0	MEC along transect on surface, 5-in armor piercing high explosives (APHE), 18-in length with base fuze. BIP'd 1/24/11 by EOD from NWS Earle.
Transects #1D	7	NA	0	0	
Totals	**654**	**41**	**1**	**10**	

5.1.3 MRS-3

A summary of the results of the intrusive investigations in all MRS-3 grids is shown in Table 5-3, and grid locations are shown in Figure A-5-1. The dig sheets of these grids, showing specific findings at each anomaly, are provided in Appendix C-2.

Table 5-3. Intrusive Investigation of MRS-3

Grid	DGM Anomalies	Mag & Dig Anomalies	MEC Found	MD Found	MEC/MD Description
G3-1	32	12	0	3	Miscellaneous MD frag/scrap (all anomalies)
G3-2	34	NA	0	0	
G3-3	49	NA	0	0	
G3-4	33	NA	0	0	
G3-5	41	NA	0	0	
G3-6	71	15	0	2	Miscellaneous MD frag (both)
G3-7	31	NA	0	0	
G3-8	75	NA	0	0	
G3-9	117	NA	0	0	
G3-10	62	NA	0	0	
G3-11	81	NA	0	0	
Totals	**626**	**27**	**0**	**5**	

5.1.4 MRS-4

A summary of the results of the intrusive investigations in all MRS-4 grids (and along the original transects) is shown in Table 5-4, and grid locations are shown in Figure A-5-1. The dig sheets of these grids and transects, showing specific findings at each anomaly, are provided in Appendix C-2. Photos of MEC found within this MRS are shown in Appendix C-4.

Table 5-4. Intrusive Investigation of MRS-4					
Grid	**DGM Anomalies**	**Mag & Dig Anomalies**	**MEC Found**	**MD Found**	**MEC/MD Description**
G4-1	118	NA	2	1	Anomalies #17 and #27 (both MEC), a 3-in Stokes mortar and 75mm shrapnel round, respectively. Demil'd to MDAS by venting (in Demo area 12/9/11)
G4-2	27	12	0	0	
G4-3	25	NA	0	0	
G4-4	47	NA	0	0	
G4-5	6	NA	0	0	
G4-6	54	NA	0	4	Miscellaneous MD scrap (one anomaly). 3 MD anomalies (#37, 45, 53), each a 75mm round, unfuzed and fired with shipping plugs. Demil'd to MDAS by venting (in Demo area 12/9/11)
G4-7	24	NA	0	0	
G4-8	23	NA	0	0	
G4-9	39	17	0	0	
G4-10	27	NA	0	0	
G4-11	14	NA	0	0	
G4-12	25	NA	0	0	
G4-13	20	NA	0	0	
G4-14	25	NA	0	0	
2A Transects	21	NA	0	0	
6A Transects *	0	NA	0	0	
Totals	**495**	**29**	**2**	**5**	

* Although no anomalies were mapped or excavated on this transect, it was included to increase the coverage in the cluster.

5.1.5 MRS-5

A summary of the results of the intrusive investigations in all MRS-5 grids is shown in Table 5-5, and grid locations are shown in Figure A-5-2. The dig sheets of these grids, showing specific findings at each anomaly, are provided in Appendix C-2. Photos of MEC found within this MRS are shown in Appendix C-4.

Table 5-5. Intrusive Investigation of MRS-5

Grid	DGM Anomalies	Mag & Dig Anomalies	MEC Found	MD Found	MEC/MD Description
G5-1	49	NA	0	0	
G5-2	57	NA	0	0	
G5-3	0*	6	0	0	
G5-4	4	NA	0	0	
G5-5	92	NA	0	0	
G5-6	47	NA	0	0	
G5-7	23	NA	0	0	
G5-8	32	NA	0	0	
G5-9	16	NA	0	0	
G5-10	79	NA	0	0	
G5-11	27	NA	1	0	Anomaly #21 (MEC), 4.5-in Mark V British AP HE round with base fuze. Demil'd in place to MDAS by venting (12/14/11)
G5-12	27	NA	0	0	
G5-13	9	NA	0	0	
G5-14	29	NA	0	0	
G5-15	28	NA	0	0	
G5-16	56	NA	0	3	Anomaly #53 (MD), 90mm AP, HE round with base fuze. Demil'd in place to MDAS by venting (12/15/11). 2 anomalies: miscellaneous MD Scrap (spent 75mm and expended 75mm schrapnel).
G5-17	67	NA	0	0	
G5-18	26	NA	0	0	
G5-19	35	NA	0	0	
G5-20	74	NA	0	1	Anomaly #28 (MD), 75mm shrapnel round, unfuzed. Moved to G5-16 (90mm) location to Demil to MDAS by venting
Totals	**777**	**6**	**1**	**4**	

* Although 15 anomalies were mapped during DGM of G5-3, during a storm, a layer of sand covered the grid prior to planned excavation. As an alternative, approval was obtained from USACE to perform mag & dig, and six anomalies were excavated.

5.1.6 MRS-6

A total of 485 anomalies in the nine grids of MRS-6 were excavated, and grid locations are shown in Figure A-5-2. No MEC or MD were found. The dig sheets of these grids, showing specific findings at each anomaly, are provided in Appendix C-2.

5.1.7 MRS-7

A total of 44 anomalies in three grids, and 52 anomalies along the original meandering path in MRS-7, were excavated, and grid locations are shown in Figure A-5-2. No MEC or MD were found. The dig sheets of these grids and transects, showing specific findings at each anomaly, are provided in Appendix C-2.

5.1.8 MRS-8

VRHabilis divers conducted intrusive operations on marine Transects 1, 2, 3A, and 3B, from their dive trailer with navigation assistance and oversight by ERT.

All 13 anomalies on Transect 1 and 38 of the 41 anomalies on Transects 2, 3A, and 3B were investigated by October 31, 2011. Inclement weather began November 1 and was forecast for the following week. With no MEC or MD found, the project team concluded that it was not critical to the project objectives to investigate the remaining three marine anomalies.

Figures A-5-3 and A-5-4 present the transects and the 54 total marine anomalies at a larger scale.

No MEC or MD were found in MRS-8. Several submerged concrete structures were found, as well as several pipes and debris piles. Examples are shown in Photos 11 to 14, Appendix H-3. The dig sheets of Transects 1, 2, 3A, and 3B, showing specific findings at each anomaly, are provided in Appendix C-3.

5.1.9 PAOI: Kingman-Mills

A total of 51 anomalies around Battery Kingman-Mills were excavated within the 0.48 acres investigated by meandering path DGM. No MEC or MD were found. The dig sheet of this PAOI, showing specific findings at each anomaly, is provided in Appendix C-2.

5.1.10 PAOI: 9-Gun Battery

A total of 45 anomalies around the 9-gun Battery were excavated within the 0.57 acres investigated by meandering path DGM. MD (scrap and fragments) was found at two locations (anomalies 12 and 22). No MEC was found. The dig sheet of this PAOI, showing specific findings at each anomaly, is provided in Appendix C-2.

5.1.11 MEC Summary

Key MEC and/or MD findings are shown in Figures A-5-1 and A-5-2 and are summarized in detail in Table 5-6.

Area	Item	Date Found	DGM anomaly	NJ State Plane Coordinates (survey feet)		Comments	Disposition
				Easting	Northing		
MRS-2 Transect	5-in AP, HE, 18-in length with base fuze	1/24/2011	on surface	633004.0	591414.0	**MEC item**. Had to be BIP'd by EOD based on size.	BIP'd 1/24/11 by EOD from NWS Earle
MRS-1, Grid 1-16	3.5-in diameter, 9-in length with base fuze	3/25/2011	64	631153.7	596412.0	**MEC item**	BIP'd 3/25/11 by EOD from NWS Earle
	Five 6-inch projectiles (empty), Two 4.7-inch projectiles (empty), Two 3.5-inch projectiles (empty), Four 75mm projectiles (empty)	3/25/2011	48 50	631165.0 631159.2	596393.9 596395.2	All were empty casings and considered to be MD	MDAS stored in drum until transfer to NPS or scrapper
MRS-1, Grid 1-10	MK 1, 1-lb, 1.44-in diameter, 3-in length	3/30/2011	47	631963.4	595661.4	**MEC item**	BIP'd 3/30/11
MRS-1, Grid 1-6	75mm projectile, fuzed and fired	11/10/2011	7	631704.9	594506.4	**MEC item**	BIP'd 11/11/11
MRS-4, Grid 4-6	**3 items** - 75mm rounds, unfuzed and fired with shipping plugs in	12/7/2011	37 45 53	635181.0 635153.6 635107.6	587768.8 587788.6 587891.5	Determined to be proof rounds (MD)	Demil'd to MDAS by venting (in Demo area 12/9/11)

Table 5-6. MEC/MD Summary of Findings

Area	Item	Date Found	DGM anomaly	NJ State Plane Coordinates (survey feet)		Comments	Disposition
				Easting	Northing		
MRS-4, Grid 4-1	**2 items** - 75mm shrapnel round, and a 3-in Stokes mortar	12/9/2011	17 (Stokes) 27 (75mm)	635340.7 635314.9	587262.1 587276.2	**2 MEC items**. Both contained minor amounts of energetics and were considered live	Demil'd to MDAS by venting (in Demo area 12/9/11)
MRS-5, Grid 5-11	4.5-in Mark V British AP HE round with base fuze	12/12/2011	21	635895.6	584719.7	**MEC item**	BIP'd 12/14/11
MRS-5, Grid 5-16	90mm AP, HE round with base fuze	12/15/2011	53	635490.8	586781.3	Round was empty and considered to be MD	Demil'd in place to MDAS by venting (12/15/11)
MRS-5, Grid 5-20	75mm shrapnel round, unfuzed	12/15/2011	28	635877.3	586434.9	Round was empty and considered to be MD	Moved to G5-16 (90mm) location to demil to MDAS by venting

* Table represents all MEC and prominent MD items encountered; numerous other small pieces of MD frag were found that are not included on this table.
Notes: BIP is blown-in-place. MDAS is material documented as safe. Demil is demilitarized.

5.2 Analysis of MEC Intrusive Investigation Findings

5.2.1 Overview

As previously described in Section 4.1.3.3, UXO Estimator (v2.2) was used to determine the coverage requirement in each cluster, using the hypothesis of 5 UXO/acre. Based on this analysis, the number of grids proposed to approximate the minimum coverage within a cluster was approved by USACE, allowing calculation of MEC or MD density within the cluster. However, due to vegetation cutting restrictions imposed by NPS, in some areas it was not possible to achieve coverage goals within the boundaries of a grid. Per the performance requirements in Appendix B of the project Statement of Work, if 90% of a grid (i.e., 9,000 square feet of a 100 feet x 100 feet grid, or 0.207 acres) could be covered by DGM, the coverage goal was considered to be met.

If less than 90% of the grid could be covered by DGM, the following procedure to increase coverage (approved by USACE and documented in page changes to the Work Plan) was employed:

A. Staying within the cluster, collect more data outside of the grid (around the perimeters), increasing the area and the equivalent percentage covered.

B. For the larger low density clusters, if space is available, add a new grid in an area where it is obvious that greater than 90% coverage could be achieved. While biased to areas with less vegetation, this was still acceptable as a means of increasing the coverage (e.g., G1-18, G2-12, G3-11, G4-14). Alternately or additionally, dig the original transect anomalies within the cluster and include the transect acreage as part of the coverage of that cluster (e.g., MRS-2 and MRS-4).

C. When it appeared in the field that enough data for the cluster had been attained, and after USACE review of the DGM data and return of the QA form, the anomalies in the grids were dug. *If no MEC or MD were found, the coverage was considered sufficient whether greater than 90% or not* because in small clusters where there is little acreage to collect additional data outside of the grid perimeters, there was limited opportunities to obtain more coverage. This was the procedure described in the Work Plan, however, it was later agreed that if no MEC or MD were found in a cluster where the coverage goal was not met, that no conclusion could be made about the presence or absence of MEC or MD in that cluster.

D. If MEC or MD were found using DGM, use mag & dig techniques in a meandering path (no vegetation removal required) to investigate the remaining portion of the grid (such that the MEC or MD-containing grid was investigated with as close to 100% coverage as possible).

E. Meandering path mag & dig could be performed in the grid with the intent of increasing coverage in the cluster, regardless of MEC or MD presence.

The options described above to increase coverage in each grid or cluster are listed in Table 5-7, with a conclusion about achievement of the coverage goal. As described in Item C above, there were areas where the coverage goal could not be met due to vegetation cutting restrictions, and in those cases, if no MEC or MD were found during the investigation, no conclusion could be made about the presence or absence of MEC or MD in that cluster. However, in cases where the coverage goal could not be met, but at least one MEC or MD item was found, a conclusion about MEC or MD presence was made. The details of these cases are described in Section 5.2.2.

The portion of a cluster covered by both DGM and mag & dig procedures is shown in Table 5-7 as "% of Cluster Covered" as a simple way to assess coverage.

With regard to investigation coverage of the NPS excluded areas, where little or no DGM coverage was obtained, no conclusions can be drawn about the presence or absence of MEC or MD in these areas denied access by NPS. A minor exception was the excluded portion of MRS-7 where some meandering path coverage was obtained, followed by intrusive investigation of anomalies. The impact of the NPS excluded areas in a particular MRS is described within the MRS level discussions in the next sections.

Information discussed in Sections 4.1 and 5.1 was compiled into Table 5-7 to enable detailed analysis of the findings. UXO Estimator was also used to evaluate the actual findings in the grids to determine various estimates of the density of MEC and MD within each cluster.

Analyses of results in each MRS are discussed in the following sections. Figures in Appendix B-4 show the clusters and grids per each MRS.

Table 5-7. Cluster Analysis, DGM Coverage, and UXO Estimator Analysis

MRS	Cluster No. [(1)]	Cluster Area (acres)	Min. Area at 5 UXO/acre	No. of Approved Grids [(2)]	90% Coverage Goal [(3)]	Grid No.	DGM Acres	Total Anomalies in Grid	No. of MEC	No. of MD	Option to Increase DGM Coverage [(4)]	Mag & Dig Acres	Total Acres (DGM + M&D)	% of Cluster Covered	90% Goal Met	Coverage Conclusion	MEC Found in Cluster (individual anomalies)	MD Found in Cluster (individual anomalies)	Average MEC Density	MEC Density at 95% Confidence	Average MEC + MD Density	MEC + MD Density at 95% Confidence	MEC/MD Hazard Area
1	C1	1.79	0.466	1	0.207	G1-1	0.22	62	0	0	N/A		0.22	12%	Y	Coverage goal met	0	0	3.987	12.291	3.987	12.291	No
	C3	1.3	0.429	1	0.207	G1-7	0.22	93	0	0	A		0.22	17%	Y	Coverage goal met	0	0	3.776	12.308	3.776	12.308	No
	C5	0.57	0.309	1	0.207	G1-8	0.10	54	0	0	A, C		0.10	18%	N	Coverage goal could not be met due to veg cutting restrictions	0	0	8.246	26.316	8.246	26.316	No
	C8	0.66	0.332	1	0.207	G1-11	0.14	95	0	0	A, C		0.14	21%	N	Coverage goal could not be met due to veg cutting restrictions	0	0	5.628	18.182	5.628	18.182	No
	C15	4.21	0.535	2	0.413	G1-12	0.22	173	0	0	N/A		0.46	11%	Y	Coverage goal met	0	0	1.936	5.938	1.936	5.938	No
						G1-13	0.23	145	0	0	N/A												
	C13	3.22	0.518	3	0.620	G1-2	0.07	5	0	0	A, C		0.51	16%	N	Coverage goal could not be met due to veg cutting restrictions	0	1	1.65	5.280	3.611	8.696	**Yes**
						G1-3	0.06	14	0	0	A, C												
						G1-4	0.38	102	0	1	A												
	C4	0.73	0.347	1	0.207	G1-6	0.07	17	1	0	A, D	0.16	0.23	32%	Y	Coverage goal met	1	0	7.326	17.808	7.326	17.808	**Yes**\5
	C6	49.04	0.594	3	0.620	G1-5	0.02	33	0	0	A, C		0.69	1%	Y	Coverage goal met	0	3	1.429	4.303	5.777	11.175	**Yes**\5
						G1-14	0.21	89	0	3	A												
						G1-17	0.23	34	0	0	N/A												
						G1-18	0.23	13	0	0	B												
	C11	1.14	0.412	1	0.207	G1-15	0.12	58	0	6	A, D	0.11	0.23	20%	Y	Coverage goal met	0	6	3.471	11.404	3.471	11.404	**Yes**\5
	C12	0.68	0.336	1	0.207	G1-16	0.10	98	1	13	A		0.10	15%	N	Coverage goal was not met	1	13	18.529	44.118	148.53	211.77	**Yes**\5
	C14	5.44	0.549	2	0.413	G1-9	0.16	158	0	0	E	0.07	0.43	8%	Y	Coverage goal met	1	0	4.467	10.662	4.467	10.662	**Yes**\5
						G1-10	0.20	79	1	0	N/A												
	B003 Area	6.5	*Not applicable – B003 Area not intended for Cluster Analysis*										0.732	11%	*Not applicable*		0	16	1.212	3.846	23.070	32.462	**Yes**\5

Table 5-7. Cluster Analysis, DGM Coverage, and UXO Estimator Analysis

MRS	Cluster No. (1)	Cluster Area (acres)	Min. Area at 5 UXO/acre	No. of Approved Grids (2)	90% Coverage Goal (3)	Grid No.	DGM Acres	Total Anomalies in Grid	No. of MEC	No. of MD	Option to Increase DGM Coverage (4)	Mag & Dig Acres	Total Acres (DGM + M&D)	% of Cluster Covered	90% Goal Met	Coverage Conclusion	MEC Found in Cluster (individual anomalies)	MD Found in Cluster (individual anomalies)	Average MEC Density	MEC Density at 95% Confidence	Average MEC + MD Density	MEC + MD Density at 95% Confidence	MEC/MD Hazard Area
2	C1	60.86	0.595	3	0.620	G2-1	0.11	32	0	0	C		0.65	1%	Y	Coverage goal met	1	0	3.06	7.263	3.06	7.263	**Yes[6]**
						G2-4	0.20	66	0	0	A												
						G2-9	0.11	53	0	0	A												
						G2-12	0.23	39	0	0	B												
						Surface find			1														
	C2	1.55	0.45	1	0.207	G2-6	0.23	13	0	0	N/A		0.23	15%	Y	Coverage goal met	0	0	3.703	11.613	3.703	11.613	No
	C1D	2.85	0.509	2	0.413	G2-2	0.20	91	0	2	A		0.43	15%	Y	Coverage goal met	0	2	1.975	6.316	6.626	13.684	**Yes[6]**
						G2-3	0.20	118	0	0	A												
						1D trans	0.02	7	0	0	B												
	C2D	4.32	0.537	3	0.620	G2-5	0.07	39	0	1	A, D	0.16	0.54	13%	N	Coverage goal met	0	3	1.620	5.093	7.176	13.657	**Yes[6]**
						G2-7	0.10	57	0	2	A, D	0.13											
						G2-8	0.08	19	0	0	A, C												
	C3D	1.31	0.43	1	0.207	G2-10	0.08	64	0	5	A, D	0.15	0.23	18%	Y	Coverage goal met	0	5	3.584	11.450	25.324	43.511	**Yes[6]**
	C4D	1.43	0.44	1	0.207	G2-11	0.16	97	0	0	A, C, E	0.07	0.23	16%	Y	Coverage goal met	0	0	3.649	11.888	3.649	11.888	No
	C5D	1.2	*Cluster probably caused by cultural features. No grids installed.*																				
3	C1	0.63	0.324	1	0.207	G3-4	0.08	33	0	0	A, C		0.08	13%	N	Coverage goal could not be met due to veg cutting restrictions	0	0	10.913	34.921	10.913	34.921	No
	C2	0.92	0.382	1	0.207	G3-6	0.10	86	0	2	A, D	0.13	0.23	25%	Y	Coverage goal met	0	2	3.261	10.870	11.957	23.913	**Yes**
	C3	5.16	0.546	3	0.620	G3-8	0.13	75	0	0	A, C		0.64	12%	Y	Coverage goal met	0	0	1.369	4.264	1.369	4.264	No
						G3-9	0.31	117	0	0	A												
						G3-10	0.20	62	0	0	A												
	C4	0.62	0.322	1	0.207	G3-3	0.13	49	0	0	C		0.13	20%	N	Coverage goal could not be met due to veg cutting restrictions	0	0	6.079	19.355	6.079	19.355	No
	C11	45.91	0.593	3	0.620	G3-2	0.12	34	0	0	A		0.76	2%	Y	Coverage goal met	0	0	1.294	3.899	1.294	3.899	No
						G3-5	0.21	41	0	0	N/A												
						G3-7	0.20	31	0	0	A												
						G3-11	0.23	81	0	0	B												
	C2A	1.07	0.403	1	0.207	G3-1	0.06	44	0	3	A, D	0.17	0.23	21%	Y	Coverage goal met	0	3	3.413	11.215	16.457	30.841	**Yes**

Table 5-7. Cluster Analysis, DGM Coverage, and UXO Estimator Analysis

MRS	Cluster No. (1)	Cluster Area (acres)	Min. Area at 5 UXO/acre	No. of Approved Grids (2)	90% Coverage Goal (3)	Grid No.	DGM Acres	Total Anomalies in Grid	No. of MEC	No. of MD	Option to Increase DGM Coverage (4)	Mag & Dig Acres	Total Acres (DGM + M&D)	% of Cluster Covered	90% Goal Met	Coverage Conclusion	MEC Found in Cluster (individual anomalies)	MD Found in Cluster (individual anomalies)	Average MEC Density	MEC Density at 95% Confidence	Average MEC + MD Density	MEC + MD Density at 95% Confidence	MEC/MD Hazard Area
4	C1	1.92	*Inside NPS excluded area. No grids installed.*																				
	C4A/ C2	5.91	0.553	3	0.620	G4-3	0.06	25	0	0	A, C		0.21	4%	N	Coverage goal could not be met due to veg cutting restrictions	0	0	4.593	13.875	4.593	13.875	No
						G4-5	0.10	6	0	0	A, C												
						G4-7	0.05	24	0	0	A, C												
	C8A/ C4	2.42	0.495	2	0.413	G4-9	0.08	56	0	0	A, E	0.16	0.42	17%	Y	Coverage goal met	0	0	1.968	6.198	1.968	6.198	No
						G4-10	0.18	27	0	0	A, C												
	C5	5.15	0.546	2	0.413	G4-1	0.26	118	2	1	A		0.49	10%	Y	Coverage goal met	2	5	5.928	12.233	16.132	26.214	**Yes**
						G4-6	0.23	54	0	4	A												
	C2A	18.84	0.584	3	0.620	G4-8	0.10	23	0	0	A, C		0.66	4%	Y	Coverage goal met	0	0	1.462	4.459	1.462	4.459	No
						G4-11	0.07	14	0	0	A, C												
						G4-12	0.10	25	0	0	A, C												
						G4-14	0.17	25	0	0	B												
						2A trans	0.22	21	0	0	B												
	C3A	1.39	0.437	1	0.207	G4-13	0.11	20	0	0	A, C		0.11	8%	N	Coverage goal could not be met due to veg cutting restrictions	0	0	8.371	25.899	8.371	25.899	No
	C5A	0.98	0.391	1	0.207	G4-2	0.13	39	0	0	E	0.10	0.23	23%	Y	Coverage goal met	0	0	3.327	11.224	3.327	11.224	No
	C6A	1.65	0.457	1	0.207	G4-4	0.20	47	0	0	N/A		0.21	13%	Y	Coverage goal met	0	0	4.156	13.333	4.156	13.333	No
						6A trans	0.01	0	0	0	B												

Table 5-7. Cluster Analysis, DGM Coverage, and UXO Estimator Analysis

MRS	Cluster No. [(1)]	Cluster Area (acres)	Min. Area at 5 UXO/acre	No. of Approved Grids [(2)]	90% Coverage Goal [(3)]	Grid No.	DGM Acres	Total Anomalies in Grid	No. of MEC	No. of MD	Option to Increase DGM Coverage [(4)]	Mag & Dig Acres	Total Acres (DGM + M&D)	% of Cluster Covered	90% Goal Met	Coverage Conclusion	MEC Found in Cluster (individual anomalies)	MD Found in Cluster (individual anomalies)	Average MEC Density	MEC Density at 95% Confidence	Average MEC + MD Density	MEC + MD Density at 95% Confidence	MEC/MD Hazard Area
5	C1	2.41	*Most of Cluster 1 is parking lot or excluded area. No grids installed.*																				
	C2	10.73	0.573	2	0.413	G5-1	0.38	49	0	0	A		0.63	6%	Y	Coverage goal met	0	0	1.495	4.567	1.495	4.567	No
						G5-2	0.25	57	0	0	A												
	C3	0.87	0.374	1	0.207	G5-3	0.24	6	0	0	E		0.24	27%	Y	Coverage goal met	0	0	3.017	10.345	3.017	10.345	No
	C4	0.82	0.365	1	0.207	G5-4	0.17	4	0	0	C		0.17	21%	N	Coverage goal could not be met due to veg cutting restrictions	0	0	4.663	14.634	4.663	14.634	No
	C11	2.78	0.507	1	0.207	G5-12	0.13	27	0	0	A, C		0.13	5%	N	Coverage goal could not be met due to veg cutting restrictions	0	0	7.33	22.302	7.33	22.302	No
	C18	2.97	0.512	2	0.413	G5-11	0.23	27	1	0	N/A		0.47	16%	Y	Coverage goal met	1	0	3.919	9.428	3.919	9.428	**Yes**
						G5-13	0.24	9	0	0	N/A												
	C19	7.34	0.561	3	0.620	G5-5	0.28	92	0	0	A		0.67	9%	Y	Coverage goal met	0	0	1.356	4.223	1.356	4.223	No
						G5-6	0.22	47	0	0	A												
						G5-7	0.17	23	0	0	A												
	C20	7	0.559	3	0.620	G5-8	0.24	32	0	0	N/A		0.64	9%	Y	Coverage goal met	0	0	1.42	4.429	1.42	4.429	No
						G5-9	0.22	16	0	0	N/A												
						G5-10	0.18	79	0	0	A, C												
	C21	25.68	0.588	7	1.446	G5-14	0.14	29	0	0	A, C		1.45	6%	Y	Coverage goal met	0	4	0.651	1.986	3.409	6.192	No
						G5-15	0.26	28	0	0	A												
						G5-17	0.27	67	0	0	A												
						G5-18	0.03	26	0	0	A, C												
						G5-19	0.18	35	0	0	A												
						G5-16	0.30	56	0	3	A												**Yes**\7
						G5-20	0.27	74	0	1	A												**Yes**\7

Table 5-7. Cluster Analysis, DGM Coverage, and UXO Estimator Analysis

MRS	Cluster No. (1)	Cluster Area (acres)	Min. Area at 5 UXO/acre	No. of Approved Grids (2)	90% Coverage Goal (3)	Grid No.	DGM Acres	Total Anomalies in Grid	No. of MEC	No. of MD	Option to Increase Coverage (4)	Mag & Dig Acres	Total Acres (DGM + M&D)	% of Cluster Covered	90% Goal Met	Coverage Conclusion	MEC Found in Cluster (individual anomalies)	MD Found in Cluster (individual anomalies)	Average MEC Density	MEC Density at 95% Confidence	Average MEC + MD Density	MEC + MD Density at 95% Confidence	MEC/MD Hazard Area
6	C1	1.33	0.431	1	0.207	G6-1	0.23	61	0	0	N/A		0.23	18%	Y	Coverage goal met	0	0	3.596	11.278	3.596	11.278	No
	C2	0.91	0.38	1	0.207	G6-2	0.23	24	0	0	N/A		0.23	25%	Y	Coverage goal met	0	0	3.249	10.989	3.249	10.989	No
	C3	0.91	0.38	1	0.207	G6-3	0.23	106	0	0	N/A		0.23	25%	Y	Coverage goal met	0	0	3.249	10.989	3.249	10.989	No
	C4	2.98	0.512	2	0.413	G6-4	0.22	55	0	0	N/A		0.45	15%	Y	Coverage goal met	0	0	1.887	6.04	1.887	6.04	No
						G6-5	0.22	65	0	0	N/A												
	C7	0.6	0.317	1	0.207	G6-9	0.23	40	0	0	N/A		0.23	39%	Y	Coverage goal met	0	0	2.681	10.0	2.681	10.0	No
	C8	9.27	0.569	3	0.579	G6-6	0.21	43	0	0	N/A		0.62	7%	Y	Coverage goal met	0	0	1.505	4.639	1.505	4.639	No
						G6-7	0.22	61	0	0	N/A												
						G6-8	0.19	30	0	0	N/A												
7	C1	1.66	0.458	2	0.413	G7-1	0.09	9	0	0	A, C		0.19	11%	N	Coverage goal could not be met due to veg cutting restrictions	0	0	4.661	14.458	4.661	14.458	No
						G7-2	0.10	20	0	0	A, C												
	C2	0.31	0.215	1	0.207	G7-3	0.08	15	0	0	A, C		0.08	26%	N	Coverage goal could not be met due to veg cutting restrictions	0	0	9.274	32.258	9.274	32.258	No
	C3	0.67	*Inside NPS excluded area. No grids installed.*																				

Notes:

1. Cluster names, locations, and orientation are based on the original VSP files from which they were generated, as confirmed via emails from ERT to USACE (between 23 February and 19 April, 2011). Cluster numbers may not be sequential due to merging of overlapping clusters.
2. The number of grids in each cluster was approved by USACE by concurrence with emails as indicated in note 1.
3. The 90% coverage requirement was sent by USACE to ERT via email on 25 October 2011. A 100 x 100 ft grid is 10,000 sq. ft., so 90% = 9,000 sq. ft. = 0.207 acres.
4. If coverage goal not met, options described in Section 5.2.1, (A through E) were used to increase cluster coverage.
5. For logistical and practical reasons, this area combined with others to form the MEC/MD Hazard Area 1A.
6. For logistical and practical reasons, this area combined with others to form the MEC/MD Hazard Area 2A.
7. C21 in MRS-5 is a low-density cluster containing six high density clusters. The two high density clusters in which MD was found (G5-16 and G5-20) were combined to form the MEC/MD Hazard Area 5A.

Some of the calculated values in these columns were not used to make conclusions about MEC/MD because low coverage caused anomalously high and misleading densities in some cases.
D – High Density Cluster
M&D – mag and dig

5.2.2 <u>Derivation of MEC/MD Hazard Areas</u>

UXO Estimator was used to evaluate the findings in the grids within each MRS to determine various estimates of the density of MEC and MD within each cluster, as shown in Table 5-7. The area of the cluster, the sum of both DGM and mag & dig coverage, the desired confidence level of 95%, and the actual number of MEC and MD items found in each cluster were entered ("confidence" is defined as the chance that the results obtained would not occur randomly; 95% is the USACE requirement for use of this software.) The software outputs an "average UXO density" which is independent of desired confidence level using a simple formula. It also outputs the "UXO density at 95% confidence" using a more complex algorithm; this number is always higher than the average UXO density and may be considered an upper limit to the estimate of density of UXO in the cluster.

The grids in which MEC or MD was found were developed into "MEC/MD Hazard Areas" by using the portion of the cluster in which the grid was contained. However, for MRS-1 and MRS-2, a larger footprint was drawn around multiple smaller clusters of MEC or MD to conservatively represent the hazard area. In these two cases, the MEC/MD Hazard Area footprint is larger than the original cluster. All MEC/MD Hazard Areas are considered to have a moderate to high probability of encountering MEC. Areas where original transects were collected, but where no clusters were identified, are considered to have a low probability of encountering MEC/MD.

These probability designations are defined in USACE pamphlet Engineering Pamphlet 75-1-2, which prescribes avoidance and safety support procedures required for project sites potentially containing MEC. That document states that "low probability of encountering MEC means that current or previous land use leads to an initial determination that MEC may be present. Moderate to high probability of encountering MEC means that current or previous land use leads to a determination that MEC was employed or disposed of in the area of concern." Further, the DoD Explosive Safety Board (DDESB) explosive safety standard 6055.9 STD defines a "low" determination as one that may only be assigned to those areas for which a search of available historical records and onsite investigation data indicates that, given the military or munitions-related activities that occurred at the site, the likelihood that UXO or other munitions and explosives of concern (MEC) are present is low. A "moderate to high" determination may be assigned to those areas for which a search of available historical records or onsite investigation data indicates that, given the military or munitions-related activities that occurred at the site, there is more than a low probability that UXO or other MEC are present.

Please note that while the hypothesis used in the UXO Estimator statistical design of the investigation was based on 5 UXO/acre (see DQO Table 3-2a and Section 4.1.3.3), areas categorized as "low probability", where no MEC or MD was found, <u>and</u> where the coverage goal was not achieved, could still contain MEC or MD items. However, the potential density of MEC (i.e., UXO/acre) cannot be estimated if the coverage goal was not met. The few places where this occurred are detailed in the following paragraphs on an MRS basis.

The details of the process of identification of MEC/MD Hazard Areas as applied to the terrestrial MRSs are discussed in Sections 5.2.2.1 through 5.2.2.7. The individual MRS figures in Appendix B-4 show the grids and clusters discussed below.

Table 5-8 presents all MEC/MD Hazard Areas from the right-most column of Table 5-7, provides specific designations, and summarizes the details of each area.

5.2.2.1 MRS-1

No MEC or MD were found during the RI in low density cluster C1 or high density clusters C3, C5, C8, and C15, and these clusters are therefore considered to have a low probability of encountering MEC/MD. Excavated anomalies were primarily cultural debris.

MEC and MD were found in high density clusters C4, C11, C12, and C14, as well as grid G1-14 of C6, and the B003 Area. A polygon was drawn around all of these areas and they were designated as MEC/MD Hazard Area-1A. This area is considered to have a moderate to high probability of encountering MEC/MD.

Cluster C13 contained grid G1-4 in which one MD item was found. The southern portion of the cluster contained two grids with no MEC or MD and this portion was therefore eliminated. The remaining northern portion of the cluster was retained as a MEC/MD Hazard Area and designated as MEC/MD Hazard Area-1B. This area is considered to have a moderate to high probability of encountering MEC/MD.

PAOI 9-Gun Battery, while not within MRS-1, is discussed here because its meandering path investigation overlapped the MRS-1 footprint in some areas and two MD items were found. One of the MD items is physically within MRS-1 and is addressed as part of MEC/MD Hazard Area-1A in MRS-1. The other one is physically outside MRS-1 and therefore, it has been designated as MEC/MD Hazard Area PAOI-9 Gun-A. Section 5.2.2.10 discusses this area in more detail.

Table 5-8. MEC/MD Hazard Areas								
MRS	**Cluster or Area**	**Acres**	**#MEC**	**#MD**	**Average MEC Density (MEC/acre)**	**MEC Density at 95% Confidence (MEC/acre)**	**Probability of Encountering MEC/MD**	**MEC/MD Hazard Area Designation**
MRS-1	Northern MRS[\1]	28.89	**3**	39	19.76	24.78	Moderate to High	1A
MRS-1	C13, northern portion	1.51	0	1	1.968	6.640	Moderate to High	1B
MRS-2	C1D, C2D, C3D, Surface Find Area	35.99	**1**	10	2.034	4.835	Moderate to High	2A
MRS-3	C2	0.92	0	2	3.261	10.870	Moderate to High	3A
MRS-3	C2A	1.07	0	3	3.413	11.215	Moderate to High	3B
MRS-4	C5	5.15	**2**	5	5.928	12.233	Moderate to High	4A
MRS-5	C21, northern portion	3.92	0	4	1.499	4.847	Moderate to High	5A
MRS-5	C18, southern portion	2.15	**1**	0	8.231	19.535	Moderate to High	5B
PAOI 9-Gun	Portion of PAOI 9-Gun	1.194	0	1	NA[\2]	NA[\2]	Moderate to High	9 Gun-A

\1 - Includes the B003 Area, clusters C4, C11, C12, C14, part of C6, and zero MEC/MD clusters C5, C8, and C15 because of proximity to other MEC/MD clusters.
\2 – Meandering path DGM did not allow meaningful MEC density calculations.

MEC/MD Hazard Areas-1A and 1B, and MEC/MD Hazard Area PAOI-9 gun-A, are shown in Figure A-5-6.

<u>B003 Area</u>

Although the B003 Area has been incorporated into MEC/MD Hazard Area-1A based on the RI findings, a separate analysis of the data was performed incorporating the previous EE/CA findings in order to address specific objectives of the RI of further defining the extent of MEC/MD identified in the EE/CA.

During the 1998 EE/CA investigation, several MEC items (referred to as "OE" items in the EE/CA report) were excavated in grid B003. Consequently, the EE/CA described this area as an ordnance disposal area, recommending a removal action. The intent of the RI effort for B003 was to determine the extent of the anomalies associated with the B003 EE/CA grid. For the RI, this was accomplished by excavating all 325 anomalies identified on the closely spaced transects. During the excavations, only MD was found in the B003 Area during this RI (no MEC).

The findings of both investigations are shown in Figure A-5-5, including the ERT data and the EE/CA data of grids B002 and B003. While MD is scattered around the 30m x 30m B003 grid, the MEC items from the EE/CA investigation appear to be limited to the eastern half of grid B003, and that appears to be the extent of potential MEC contamination associated with this previously defined disposal area.

5.2.2.2 MRS-2

No MEC or MD were found during the RI in low density clusters C1 or C2 or in high density cluster C4D and these clusters are therefore considered to have a low probability of encountering MEC/MD. Excavated anomalies were primarily cultural debris. The individual areas of MRS-2 where MEC or MD was encountered are as follows:

- Cluster C2D contained grids G2-5, G2-7, and G2-8, in which three MD items were found.
- Cluster C3D contained grid G2-10 in which five MD items were found.
- One MEC item (5 inch APHE round) was found on the ground surface during the initial transect-cutting phase of the RI fieldwork, and removed prior to any DGM and subsequent cluster analysis (it is not considered part of cluster C1 because it was found prior to identification of the cluster).
- Cluster C1D contained grids G2-2 and G2-3, in which two MD items were found.
- Just west of G2-1, where no MEC or MD were found, the old 1998 EE/CA grid B029 was included in the MEC/MD Hazard Area-2A footprint since, according to the EE/CA, two 12-inch unfired projectiles reportedly remain in place.

All of these areas containing MEC or MD were combined (approximately 35 acres total) into MEC/MD Hazard Area-2A, which is considered to have a moderate to high probability for encountering MEC/MD. See Figure A-5-7.

Note that approximately 15.5 acres of MRS-2 were excluded from investigation by NPS (along the western margin). The MEC item found on the surface was close to this excluded area; however, no conclusions can be drawn about the presence or absence of MEC or MD in these areas denied access by NPS.

5.2.2.3 MRS-3

No MEC or MD were found during the RI in low density clusters C4 or C11, or in high density clusters C1 or C3, and these areas are considered to have a low probability of encountering MEC/MD. Excavated anomalies were primarily cultural debris. However, while no MEC or MD were found in clusters C1 and C4, the coverage goal could not be met and therefore no conclusions about presence or absence of MEC or MD can be made for these clusters; Figure A-5-8 shows these clusters as red-lined areas equivalent to NPS excluded areas.

Cluster C2 contained grid G3-6 in which 2 MD items were found, and therefore this cluster was designated as MEC/MD Hazard Area-3A. This area is considered to have a moderate to high probability of encountering MEC/MD. It is shown in Figure A-5-8.

Cluster C2A contained grid G3-1 in which 3 MD items were found, and therefore this cluster was designated as MEC/MD Hazard Area-3B. This area is considered to have a moderate to high probability of encountering MEC/MD. It is also shown in Figure A-5-8.

5.2.2.4 MRS-4

No MEC or MD was found during the RI in any clusters in MRS-4 with the exception of high density cluster C5. The MRS, excluding C5, is considered to have a low probability of encountering MEC/MD.

Cluster C5 contained grids G4-1 and G4-6 in which 2 MEC items and 5 MD items were found, and therefore this cluster was designated as MEC/MD Hazard Area-4A. This area is considered to have a moderate to high probability of encountering MEC/MD. It is shown in Figure A-5-9. This MEC/MD Hazard Area falls in the center of the historical 3,000-yard impact area.

Note that approximately 18.4 acres of MRS-4 were excluded from investigation by NPS (along the western margin). A small amount of geophysical data was collected along the eastern margin of the excluded area along an existing path, and four grids were investigated within 100 feet of the boundary with no MEC or MD found. Otherwise, no conclusions can be drawn about the presence or absence of MEC or MD in these areas denied access by NPS. However, while no MEC or MD were found in clusters C3A and C4A, the coverage goal could not be met, and therefore no conclusions about presence or absence of MEC or MD can be made for these clusters; Figure A-5-9 shows these clusters as red-lined areas equivalent to NPS excluded areas.

5.2.2.5 MRS-5

Approximately 83 acres of MRS-5 was excluded from investigation by NPS (along the western margin). A small amount of geophysical data was collected along the eastern margin of the excluded area along existing paths, and three grids were investigated within 100 feet of the boundary with no MEC or MD found.

No MEC or MD were found during the RI in low density clusters C2, C3, C4, C11, C19 or C20, and these areas are considered to have a low probability of encountering MEC. Excavated anomalies were primarily cultural debris. However, while no MEC or MD were found in clusters C4 and C11, the coverage goal could not be met, and therefore no conclusions about presence or absence of MEC or MD can be made for these clusters; Figure A-5-10 shows these clusters as red-lined areas equivalent to NPS excluded areas.

Cluster C21 contained seven grids, and a total of four MD items were found in grids G5-16 and G5-20. Cluster C21 is a low density cluster, and as explained in Section 4.1.3.3, high density clusters within C21 were used as a guide to place grids. The high-density clusters that contained grids with no MEC or MD were eliminated from further analysis, leaving the two northernmost clusters. These were combined into a single area designated as MEC/MD Hazard Area-5A. This area is considered to have a moderate to high probability of encountering MEC/MD. MEC/MD Hazard Area-5A is shown on Figure A-5-10.

Cluster C18 contained grids G5-11 and G5-13 in which one MEC item was found. The northern portion of the cluster contained one grid with no MEC or MD and thus it was eliminated from further analysis. Based on the presence of MEC, the remaining southern portion of the cluster was designated as MEC/MD Hazard Area-5B. This area is considered to have a moderate to high probability of encountering MEC. It is also shown on Figure A-5-10.

Approximately 83 of the 205 acres of MRS-5 were excluded from investigation by NPS (along the western margin). A small amount of geophysical data was collected along the eastern margin of the excluded area along existing paths, and three grids were investigated within 100 feet of the boundary with no MEC or MD found. Otherwise, no conclusions can be drawn about the presence or absence of MEC or MD in the MRS-5 areas denied access by NPS.

5.2.2.6 MRS-6

No MEC or MD were found during the RI in any clusters in MRS-6. No MEC Hazard Areas are identified in this MRS, and this MRS is considered to have a low probability of encountering MEC/MD. Excavated anomalies were primarily cultural debris.

5.2.2.7 MRS-7

Because approximately 83% (24.2 of 29 acres) of MRS-7 was excluded from investigation by NPS, very little of the MRS could be investigated in a systematic way, which lessened the ability to provide the statistically supported conclusions related to this MRS. For this reason all anomalies mapped by the meandering path transects were intrusively investigated.

Three low density clusters are present in MRS-7 in areas where transect spacing was sufficient for cluster analysis to be meaningful. No MEC or MD were found during the RI in clusters C1 or C2 and they are considered to have a low probability of encountering MEC. Excavated anomalies were primarily cultural debris.

Cluster C3, at the center of the MRS (the site of the explosion of the former magazine), was completely within the NPS excluded areas and could not be intrusively investigated other than the limited anomalies on the meandering path. No MEC or MD were found during the RI on the meandering path. Due to low coverage on the meandering path within the excluded area, only a qualitative statement can be made that no MEC or MD were found in the area. Otherwise, no conclusions can be drawn about the presence or absence of MEC or MD in the MRS-7 areas denied access by NPS.

However, for the investigated portion of MRS-7 (4.8 acres), no MEC/MD Hazard Areas were identified and it is therefore considered to have a low probability of encountering MEC.

5.2.2.8 MRS-8

No cluster analysis was performed in marine MRS-8 (it is not included in Table 5-7). However, the MEC/MD density was evaluated using UXO Estimator. The area of MRS is approximately 153 acres. The area covered by the DGM investigation was 9.08 acres. While no MEC or MD were found, not all anomalies were investigated, as described in Section 5.1.8. Assuming the three uninvestigated anomalies were not MEC or MD, the following statistical conclusions may be drawn:

- The average UXO density is 0.104 MEC/acre, and
- The UXO density at 95% confidence is 0.314 MEC/acre.

Assuming a worst-case scenario, that three MEC items were found in the MRS, the average UXO density would be 0.434 MEC/acre and the UXO density at a 95% confidence level would be 5.763 MEC/acre. Therefore the overall probability of encountering MEC/MD in marine MRS-8 is considered to be low.

5.2.2.9 PAOI: Kingman-Mills

The goal for the PAOIs, which are outside of the MRS boundaries, was to determine presence or absence of MEC or MD by meandering path followed by excavation of all anomalies; no statistical evaluation was intended. No MEC or MD were found in PAOI Kingman-Mills Battery within the 0.48 acres investigated by meandering path DGM. This PAOI is considered to have a low probability of encountering MEC/MD.

5.2.2.10 PAOI: 9-Gun Battery

PAOI 9-gun Battery was also investigated by meandering path followed by excavation of all anomalies. No MEC was found; minor amounts of MD (scrap and fragments) were found in two anomalies within the 0.57 acres investigated by meandering path DGM. As described in Section 5.2.2.1, one of the MD items found was within MEC/MD Hazard Area-1A. The area of the other MD item was developed into MEC/MD Hazard Area-PAOI-9 Gun-A, and it is considered to have a moderate to high probability of encountering MEC/MD. MEC/MD Hazard Area-PAOI-9 Gun-A is shown in Figure A-5-6. The remaining portion of this PAOI is considered to have a low probability of encountering MEC/MD.

5.2.2.11 Relevant 1998 EE/CA Findings

The 1998 EE/CA is generally described in section 1.4.4. This discussion provides additional detail on the actual findings as they are relevant to providing a more complete picture of MEC and/or MD at the site. Based on Table 1-4 of the EE/CA, relevant findings are presented on Figure A-5-11. Grids where “UXO/OE” (following the terminology of the EE/CA document) items were found are shown as dark blue squares and grids where “UXO-Related Scrap” items were found are shown as light blue squares. EE/CA grids were placed in accessible locations within ten areas designated A through J. Only cultural debris was found in Area C, Area G, Area I, and Area J. Only two small arms bullets were found in Area D, and Area H was not investigated due to ongoing beach replenishment at the time. Therefore, no grids are shown in Areas C, D, G, H, I, or J on Figure A-5-11.

Grids containing UXO/OE or UXO-Related scrap within Area B, Area E, or Area F, lie within the seven MRSs of this RI. Almost all of the UXO/OE or scrap finds fall within the MEC/MD Hazard Areas summarized in Table 5-8, or within MRS-7, and are consistent with the CSMs for those associated MRSs. Area A (Historic Fort Hancock), where three UXO/OE items (3-inch, 8-inch, and 10-inch projectiles) and some UXO-Related Scrap items were found, is to the west of MRS-1 of the RI. The source of these Area A items is not known, and although they fall outside of the current MRSs, they will be addressed in the future Feasibility Study (FS). It will be acknowledged in the FS that based on these findings outside of the current MRS footprints, the potential exists for MEC and/or MD to be found anywhere on the Sandy Hook peninsula.

5.3 Munitions Constituents Findings

Environmental sampling of soil, surface water, sediment, and groundwater for MC was completed as described in Section 4.2. The data summary tables for all samples are presented in Appendix F-1. A formal screening of the data to identify chemicals of potential concern (COPCs) is contained in the baseline risk assessment Section 6.0. In accordance with the Work Plan, sample results from the 2006 SI are incorporated into the overall assessment of risk presented in Section 6.0. However, the discussions below focus on the results of the RI sampling.

5.3.1 Soil Samples

Seven IS soil samples associated with BIP activities were collected from three different MRSs (MRS-1, MRS-2, and MRS-5). Twenty-one random discrete soil samples were collected to characterize the Livens Area (MRS-7). The analytical results of the soil samples were used to complete a "hot spot" analysis to determine whether an expanded groundwater investigation was warranted.

5.3.1.1 IS (BIP)

Because IS samples are composites, they were qualitatively assessed against New Jersey background standards, as discussed in Section 6.0. The analytical result for each IS sample represents the exposure point concentration for the 30-ft by 30-ft area from which the sample was collected.

The IS soil samples were analyzed for select metals and explosives. No explosives compounds were found above the detection limit in any sample. Metals analysis included antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc. Each of these metals was detected at least once in the samples. None of the metals were found at levels inconsistent with background concentrations and they likely represent naturally occurring background conditions.

The intent of the samples is to determine whether MC was released during detonation by assessing pre- and post-BIP conditions. However, due to safety concerns, only one pre and post BIP sample set could be collected. Sample FHRI-01-SO-03 and FHRI-01-SO-04 represent pre- and post-BIP conditions associated with a MEC find in MRS-1. Comparison of the metals detected after the BIP do not indicate that the BIP activity is contributing to metals contamination of the soil. Some of the metals concentrations in the pre-BIP sample were higher than the post-BIP concentration. Formal risk assessment of the BIP results is presented in Section 6.2.3.9.

5.3.1.2 Random Discrete (MRS-7)

The 21 random discrete surface soil samples were collected from the Livens Discovery Area (MRS-7) where the 1927 bunker/storehouse explosion occurred. The samples were analyzed for select metals and explosives.

No explosives compounds were found above the detection limit in any sample. Metals analysis included antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc. Each of these metals was detected at least once in the samples. None of the metals were found at levels inconsistent with background concentrations and they likely represent naturally occurring background conditions.

5.3.1.3 "Hot Spot" Analysis

As documented in the TPP Memorandum (TPP #2 Memorandum of Appendix I of the Work Plan), NJDEP did not believe a groundwater investigation was warranted at Fort Hancock. It was decided that a soil "hot spot" (e.g., contamination in excess of screening values for the soil-to-groundwater migration pathway) would have to be identified as a condition for an expanded groundwater investigation that would include installing new wells. The screening level evaluation process used to determine possible soil "hot spots" and to assess their potential to impact groundwater is included in the groundwater DQO (Table 3-2d).

The analytical results for all the soil samples were compared to the protection of groundwater Soil Screening Levels (SSLs) from the November 2011 Regional Screening Level table (note the screening was performed prior to when the May 2012 RSLs were published and the field decisions were based on the November RSL values). The SSLs were multiplied by a default dilution and attenuation factor (DAF) of 20. For analytes with a maximum contaminant level (MCL), the SSL was based on the MCL value.

Arsenic was the only metal detected at concentrations greater than the SSL (DAF = 20). Four arsenic detections were greater than the SSL of 5.8 mg/kg. The maximum concentration, 12.7 mg/kg (FHRI-01-SO-02-MIS), was less than the background value of 19 mg/kg identified in the New Jersey Soil Remediation Standards Table. This comparison indicates that the arsenic represents natural background conditions, not a contaminant "hot spot".

In summary, comparison of the analytical results to screening values protective of groundwater quality and to background levels indicates the absence of potential contamination that could pose a threat to the underlying groundwater. Based on this evaluation, the need for an expanded groundwater investigation beyond the one described in this RI was not indicated.

5.3.2 Sediment and Surface Water Samples

Three surface water and six sediment samples were collected in accordance with the procedures in the approved Work Plan. The samples were collected from Nike Pond (MRS-5) and analyzed for select metals and explosives.

No explosives compounds were found above the detection limit in any of the surface water or sediment samples. Metals analysis included antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc.

In the surface water samples, arsenic, chromium, copper, lead, manganese, thallium, titanium, vanadium, and zinc were detected. Antimony, barium, cadmium, and mercury were not detected in any surface water sample. In the sediment samples, arsenic, chromium, copper, lead, manganese, thallium, titanium, vanadium, zinc, and mercury were detected. Antimony, barium, and cadmium were not detected in any sediment sample.

As discussed in greater detail in Section 6.0, for the surface water samples, only arsenic, manganese, and thallium concentrations were found at levels higher than the screening level. The arsenic concentration was higher than the screening level in three samples, the manganese concentration was higher than the screening level in two samples, and the thallium concentration was higher than the screening level in one sample.

As discussed in greater detail in Section 6.0, for the sediment samples, only thallium concentrations were found at levels higher than the screening level. However, thallium appears to be consistent with NJ background soil concentrations.

5.3.3 Groundwater Samples

Five groundwater wells were sampled for the RI. A sixth well was dry and could not be sampled. The samples were analyzed for select metals and explosives.

No explosives compounds were found above the detection limit in any sample. Metals analysis included antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, thallium, titanium, vanadium, and zinc. Only arsenic, barium, chromium, manganese, titanium, vanadium, and zinc were detected at least once in the samples. Antimony, cadmium, copper, lead, mercury, and thallium were not detected in any of the samples.

As discussed in greater detail in Section 6.0, only arsenic (well GW2E) and manganese (well DW 01) concentrations were found at levels higher than the screening level. However, arsenic appears to be consistent with NJ background concentrations and the highest manganese concentration was from the untreated raw water of the potable drinking water well (DW 01). This well draws groundwater from a confined aquifer approximately 880 feet deep, and does not reflect the groundwater in the other sampled wells. The water is sent through a sand filter prior to consumption and routine sampling by NPS indicates that manganese concentrations are well within acceptable levels. MC constituents are unlikely to be able to impact a confined aquifer that is 880 feet deep.

As described in Section 5.3.1.3, a "hot spot" analysis did not indicate the need for a more expanded groundwater investigation.

5.3.4 IDW Investigation Results

The containerized development/purge water and decontamination water was sampled for Toxicity Characteristic Leaching Procedure (TCLP) disposal characterization, including:

- VOCs by SW-846 Method 8260B/5030B/1311
- SVOCs by SW-846 Method 8270C/3510C/1311
- Pesticides by SW-846 Method days to analysis 8081A/3510C/1311
- Herbicides by SW-846 Method 8151A/8151A/1311
- Metals by SW-846 Method 6010B/3010A/ 1311
- Flashpoint by SW-846 Method 1010

The TCLP results indicated the arsenic concentration was above the very low NJDEP GW Quality standard. However, the concentration was below the federal and NJDEP MCL, well below the TCLP standard, and most likely represents background conditions. Following consultation with the NJDEP, as confirmed in a January 31, 2012 NJDEP email, (ERT, January 2012) it was determined that the water could be discharged to the ground surface.

5.3.5 Data Quality Assessment

The analytical data provided by Accutest Laboratories, Inc. Accutest in Dayton, New Jersey, performed metals analyses and Accutest in Orlando, Florida, performed explosives analyses. The sample procedures followed by ERT were reviewed by the ERT Project Chemist and validated by the Meridian Consultant Group's Senior Chemist. The detailed data quality assessment (DQA), presented in Appendix F-3, summarizes those findings in accordance with the approved Quality Assurance Project Plan (QAPP) (ERT, 2010), and specifically evaluates the data quality indicators of precision, accuracy, reproducibility, comparability, completeness, and sensitivity (PARCCS) with respect to the project DQO. Overall, the data were considered to be of an acceptable quality to be used in this RI report.

5.4 Revised Conceptual Site Models

Section 3.0 presented the initial preliminary CSMs for the site. This section discusses changes to the CSMs based on the findings of the RI, and presents revised CSM tables and diagrams per MRS. The updated CSMs describe the current state of knowledge about hazards and risks at the site based on the DGM and MC sampling completed.

Revised CSMs are presented as Tables 5-9a through 5-9g. The intent of the tables is to highlight the changes relative to the Section 3.0 preliminary CSMs. The tables are presented on an MRS level and address the MEC/MD Hazard Areas identified in Section 5.2.2 (Table 5-8), as well as non-MEC/MD hazard areas. Updates to MC risks are also presented.

Figures A-5-12 through A-5-16 show MEC/MD source-interaction-receptors for individual MRSs, with both the MEC/MD Hazard Areas and the non-MEC/MD contaminated areas presented on a single figure for that MRS. Figure A-5-17 groups MRSs 6, 7, and 8 because no MEC/MD were found and the diagrams are similar.

Figures A-5-18 through A-5-21 address the MC source-interaction-receptors for individual MRSs, with MRSs 1, 2, 3, 4, 6, and 7 grouped on one figure (A-5-18) because of the lack of an MC source, and the B003 Area and MRS-5 having separate CSM diagrams (A-5-19 and A-5-20, respectively) to better describe the impact of the RI findings, and MRS-8 having a separate CSM figure (A-5-21) because of the differing scenario relative to the land MRSs.

5.4.1 <u>MRS-1</u>

For MRS-1 (other than the B003 Area), Table 5-9a shows that MC receptors are present; however, exposure routes and MC migration pathways are considered incomplete for soil and groundwater (see Figure A-5-18). The Risk Assessment concludes there are no MC issues for this MRS.

For the B003 Area within MRS-1, exposure routes and MC migration pathways are considered complete for soil, but incomplete for groundwater (see Figure A-5-19). The risk assessment concludes that arsenic and lead could pose a risk to human receptors and antimony, arsenic, copper, lead, selenium and thallium could pose a risk to ecological receptors.

For MEC/MD Hazard Areas-1A and 1B, MEC/MD is present on the surface and in the subsurface soil. Receptors are potentially present, pathways are considered complete, and exposure routes are considered complete (excluding non-intrusive activities in the subsurface soil). As explained in Section 5.2.2.1, MEC/MD Hazard Area PAOI-9 Gun-A is included in this discussion based on proximity. Similar to 1A and 1B, receptors are potentially present, pathways are considered complete, and exposure routes are considered complete (excluding non-intrusive activities in the subsurface soil). See Figure A-5-12.

For the non-MEC/MD contaminated area of MRS-1 and PAOI-9 gun, receptors are potentially present but pathways are considered incomplete because there is no MEC/MD source and exposure routes are incomplete.

5.4.2 MRS-2

For MRS-2, Table 5-9b shows that MC receptors are present; however, exposure routes and migration pathways are considered incomplete for soil and groundwater (see Figure A-5-18). The Risk Assessment concludes there are no MC issues for this MRS.

For MEC/MD Hazard Area-2A MEC/MD is present on the surface and/or in the subsurface soil. Receptors are potentially present, pathways are considered complete, and exposure routes are considered complete (excluding non-intrusive activities in the subsurface soil). See Figure A-5-13.

For the non-MEC/MD contaminated area of MRS-2, receptors are potentially present but pathways are considered incomplete because there is no MEC/MD source and exposure routes are incomplete. However, note that no conclusions can be drawn about the presence or absence of MEC or MD in the minor excluded portions of MRS-2 denied access by NPS.

5.4.3 MRS-3

For MRS-3, Table 5-9c shows that MC receptors are present; however, exposure routes and MC migration pathways are considered incomplete for soil and groundwater (see Figure A-5-18). The Risk Assessment concludes there are no MC issues for this MRS.

For MEC/MD Hazard Areas-3A and 3B, MD is present on the surface and in the subsurface soil. Receptors are potentially present, pathways are considered complete, and exposure routes are considered complete (excluding non-intrusive activities in the subsurface soil).

For the non-MEC/MD contaminated area of MRS-3, receptors are potentially present but pathways are considered incomplete because there is no MEC/MD source and exposure routes are incomplete. See Figure A-5-14.

5.4.4 MRS-4

For MRS-4, Table 5-9d shows that MC receptors are present; however, exposure routes and MC migration pathways are considered incomplete for soil and groundwater (see Figure A-5-18). The Risk Assessment concludes there are no MC issues for this MRS.

For MEC/MD Hazard Area-4A, MEC/MD is present on the surface and in the subsurface soil. Receptors are potentially present, pathways are considered complete, and exposure routes are considered complete (excluding non-intrusive activities in the subsurface soil). The 2 MEC and 5 MD items were found within the impact area, and the average MEC+MD density suggests that the preliminary CSM of an impact area is confirmed.

For the non-MEC/MD contaminated area of MRS-4, receptors are potentially present but pathways are considered incomplete because there is no MEC/MD source and exposure routes are incomplete. However, note that no conclusions can be drawn about the presence or absence of MEC or MD in the excluded portions of MRS-4 denied access by NPS. See Figure A-5-15.

5.4.5 MRS-5

For MRS-5, Table 5-9e shows that MC receptors are present; however, exposure routes and MC migration pathways are considered incomplete for soil and groundwater. Exposure routes are considered complete and migration pathways complete for surface water and sediment, (see Figure A-5-20). However, the Risk Assessment concludes there are no MC issues for this MRS.

For MEC/MD Hazard Area-5A, MD is present on the surface and in the subsurface soil, and for Area-5B, MEC may be present in the surface and in the subsurface soil. Receptors are potentially present, pathways are considered complete, and exposure routes are considered complete (excluding non-intrusive activities in the subsurface soil).

For the non-MEC/MD contaminated area of MRS-5, receptors are potentially present but pathways are considered incomplete because there is no MEC/MD source and exposure routes are incomplete. However, note that no conclusions can be drawn about the presence or absence of MEC or MD in the excluded portions of MRS-5 denied access by NPS. See Figure A-5-16.

5.4.6 MRS-6

For MRS-6, Table 5-9f shows that MC receptors are present; however, exposure routes and MC migration pathways are considered incomplete for soil and groundwater (see Figure A-5-18). The Risk Assessment concludes there are no MC issues for this MRS.

For MEC/MD, receptors are potentially present but pathways are considered incomplete because there is no MEC/MD source and exposure routes are incomplete. However, note that no conclusions can be drawn about the presence or absence of MEC or MD in the minor excluded portions of MRS-6 denied access by NPS. See Figure A-5-17.

5.4.7 MRS-7

For MRS-7, Table 5-9f shows that MC receptors are present; however, exposure routes and MC migration pathways are considered incomplete for soil and groundwater (see Figure A-5-18). The Risk Assessment concludes there are no MC issues for this MRS.

For MEC/MD, receptors are potentially present but pathways are considered incomplete because there is no MEC/MD source and exposure routes are incomplete. However, note that no conclusions can be drawn about the presence or absence of MEC or MD in the significant excluded portions of MRS-7 denied access by NPS. See Figure A-5-17.

5.4.8 MRS-8

For MRS-8, Table 5-9g shows that MC receptors are present; however, exposure routes and MC migration pathways are considered incomplete for sediment and surface water (see Figure A-5-21). The Risk Assessment concludes there are no MC issues for this MRS.

For MEC/MD, receptors are potentially present but pathways are considered incomplete because there is no MEC/MD source and exposure routes are incomplete. See Figure A-5-17.

Table 5-9a. Revised Conceptual Site Model for MRS-1

Profile Type	Site Characterization
Facility Profile	**Location and Area:** • No change from Table 3-1a. • RI findings indicate that there are two MEC/MD Hazard Areas within MRS-1. MEC/MD Hazard Area-1A is located in the northern portion of MRS-1 and is 28.9 acres in total area. B003 is located within MEC/MD Hazard Area-1A. MEC/MD Hazard Area-1B is located in the central portion of MRS-1 and is 1.51 acres in total area. MEC/MD Hazard Area-PAOI-9 Gun-A is located off the northeast corner of MRS-1 and is 1.19 acres in area.
	Structures: • No change from Table 3-1a. • MEC/MD Hazard Area-1A is within the northern half of the MRS, which includes the structures in Table 3-1a. MEC/MD Hazard Area-1B has no structures nearby. PAOI-9 Gun-A is east of the battery, in a wooded area.
	Boundaries: • No change from Table 3-1a. • MEC/MD Hazard Area-1A is approximately bounded to the north by woodlands, to the south by beach and woodlands, to the west by woodlands, and to the east by the beach dunes. MEC/MD Hazard Area-1B is bounded by woodlands, and PAOI-9 Gun-A is mostly woodlands on the east side of the battery.
	Security: • No change from Table 3-1a. • MEC/MD Hazard Area-1A is partially covered by dense vegetation (woody and herbaceous), which limits access to parts of the area, but the road, beach house, and parking lot are accessible. MEC/MD Hazard Area-1B is not accessible, but PAOI-9 Gun-A is accessible from the parking lot.
	Utilities: • No change from Table 3-1a. • There are no utilities within MEC/MD Hazard Area-1A, 1B, or PAOI-9 Gun-A.
Physical Profile	**Topography:** • No change from Table 3-1a. • Dunal topography is present on MEC/MD Hazard Area-1A 1B, and PAOI-9 Gun-A with a slight elevation increase moving westward.
	Vegetation: • No change from Table 3-1a. • Similar vegetation can be found within all three MEC/MD Hazard Areas.
	Wetlands: • No change from Table 3-1a. • A portion of a wetland is located at the southern end of MEC/MD Hazard Area-1A. There are no wetlands within 1B or PAOI-9 Gun-A.
	Soil: • No change from Table 3-1a. • Similar soils can be found within all three MEC/MD Hazard Areas.
	Hydrology: • No change from Table 3-1a. • There are no surface water bodies within or near the three MEC/MD Hazard Areas.

Table 5-9a. Revised Conceptual Site Model for MRS-1	
Profile Type	**Site Characterization**
	Hydrogeology/Geology: • No change from Table 3-1a.
Land Use and Exposure Profile	**Current Land Use:** • No change from Table 3-1a.
	Cultural, Archaeological and Historical Resources: • No change from Table 3-1a.
	Current Potential Human Receptors: • No change from Table 3-1a.
	Potential Future Land Use: • No change from Table 3-1a.
	Potential Future Human Receptors: • No change from Table 3-1a.
Ecological Profile	**Degree of Disturbance:** • No change from Table 3-1a.
	Habitat Types: • No change from Table 3-1a.
	Current Potential Ecological Receptors: • No change from Table 3-1a.
Munitions Release Profile	**Munitions Types:** • MEC items found in MEC/MD Hazard Area-1A during the RI include a 3.5 inch Armor Piercing High Explosive (APHE) round with a base fuze, a Mk2, 1 lb round, and a 75 mm round with a fuze.
	Release Mechanisms: • No change from Table 3-1a.
	MEC Density: • Average MEC density for MEC/MD Hazard Area-1A is 19.76 MEC per acre, and for MEC/MD Hazard Area-1B is 1.968 MEC per acre. For PAOI-9 Gun-A, no MEC density calculations could be performed for the meandering path data.
	Associated Munitions Constituents: • Groundwater was assessed as a single exposure unit across all MRSs. Manganese was detected from a well (not within any MRS) installed at 880 ft bgs. Because of this extreme depth, the groundwater sample is not believed to reflect any potential site-related contamination. No MC contaminants were detected above background in any of the four shallow groundwater samples. • Soil data from the 2006 SI for non-B003 Area samples showed all metals within background range (8 surface soil samples were collected during the SI and analyzed for explosives and TAL metals). However, in the B003 Area, per the Risk Assessment, antimony, arsenic, copper, lead, selenium and thallium were metals of concern based largely on one soil sample. • No breached MEC items, bulk explosives, or concentrated MD were found that warranted sampling during the RI. By inference from the approved Work Plan, which did not call for soil sampling unless such conditions were found, there is no source of MC, outside of the potential source in the B003 Area, as shown by SI samples.

Table 5-9a. Revised Conceptual Site Model for MRS-1

Profile Type	Site Characterization
	Transport Mechanisms/Migration Routes: • Transport mechanisms and migration routes for MEC, MD, and MC remain the same after the RI.
	Pathway Analysis: • MC: - For MRS-1 (other than the B003 Area), receptors are potentially present; however, exposure routes and MC migration pathways are considered incomplete for soil and groundwater as there is no identified source of MC (see Figure A-5-18). The Risk Assessment concludes there are no MC issues. - For B003, exposure routes and MC migration pathways are considered complete for soil, but incomplete for groundwater (see Figure A-5-19). The Risk Assessment concludes that arsenic and lead could pose a risk to human receptors and antimony, arsenic, copper, lead, selenium and thallium could pose a risk to ecological receptors. • MEC/MD: (See Figure A-5-12). - *Non-MEC/MD Hazard Areas.* Receptors are potentially present but pathways are considered incomplete because there is no source and exposure routes are incomplete. - *MEC/MD Hazard Area-1A, 1B, and PAOI-9 Gun-A.* MEC/MD may be present on the surface and in the subsurface soil. Receptors are potentially present, pathways are considered complete, and exposure routes are considered complete (excluding non-intrusive activities in the subsurface soil).

Table 5-9b. Revised Conceptual Site Model for MRS-2

Profile Type	Site Characterization
Facility Profile	**Location and Area:** • No change from Table 3-1b. • RI findings indicate one MEC/MD Hazard Area within MRS-2: - MEC/MD Hazard Area-2A is located in the central portion of MRS-2 and is 35.99 acres in total area.
	Structures: • No change from Table 3-1b. • There are no structures within or near MEC/MD Hazard Area-2A.
	Boundaries: • No change from Table 3-1b. • MEC/MD Hazard Area-2A is approximately bounded on all sides by woodlands to the north and south, but has a portion of the road running through the west side. West of the road are excluded areas. Dunes are to the east.
	Security: • No change from Table 3-1b. • MEC/MD Hazard Area-2A is partially covered by dense vegetation (woody and herbaceous), which naturally limits access to parts of the area.
	Utilities: • No change from Table 3-1b. • There are no utilities within MEC/MD Hazard Area-2A.
Physical Profile	**Topography:** • No change from Table 3-1b. • Dunal topography is present on MEC/MD Hazard Area-2A, with a slight elevation increase moving westward.
	Vegetation: • No change from Table 3-1b. • Similar vegetation can be found within MEC/MD Hazard Area-2A.
	Wetlands: • No change from Table 3-1b. • No wetlands are present in MEC/MD Hazard Area-2A.
	Soil: • No change from Table 3-1b. • Similar soils can be found within MEC/MD Hazard Area-2A.
	Hydrology: • No change from Table 3-1b. • There are no surface water bodies within or near MEC/MD Hazard Area-2A.
	Hydrogeology/Geology: • No change from Table 3-1b.
Land Use and Exposure Profile	**Current Land Use:** • No change from Table 3-1b.
	Cultural, Archaeological and Historical Resources: • No change from Table 3-1b.
	Current Potential Human Receptors: • No change from Table 3-1b.

Table 5-9b. Revised Conceptual Site Model for MRS-2

Profile Type	Site Characterization
	Potential Future Land Use: • No change from Table 3-1b.
	Potential Future Human Receptors: • No change from Table 3-1b.
Ecological Profile	**Degree of Disturbance:** • No change from Table 3-1b.
	Habitat Types: • No change from Table 3-1b.
	Current Potential Ecological Receptors: • No change from Table 3-1b.
Munitions Release Profile	**Munitions Types:** • MEC/MD Hazard Area-2A. One MEC item and 10 MD items were found in this area.
	Release Mechanisms: • No change from Table 3-1b. • Note that no conclusions can be drawn about the presence or absence of MEC or MD in the minor excluded portions of MRS-2 denied access by NPS.
	MEC Density: • Average MEC density for MEC/MD Hazard Area-2A (surface find) is 2.034 MEC per acre.
	Associated Munitions Constituents: • Groundwater was assessed as a single exposure unit across all MRSs. Manganese was detected from a well (not within any MRS) installed at 880 ft bgs. Because of this extreme depth, the groundwater sample is not believed to reflect any potential site-related contamination. No MC contaminants were detected above background in any of the four shallow groundwater samples. • No breached MEC items, bulk explosives, or concentrated MD were found that warranted sampling during the RI. By inference from the approved Work Plan, which did not call for soil sampling unless such conditions were found, there is no source of MC.
	Transport Mechanisms/Migration Routes: • Transport mechanisms and migration routes for MEC, MD, and MC remain the same after the RI.

Table 5-9b. Revised Conceptual Site Model for MRS-2

Profile Type	Site Characterization
	Pathway Analysis: • MC: (See Figure A-5-18) - Within MRS-2, receptors are potentially present; however, exposure routes and migration pathways are considered incomplete for soil and groundwater as there is no identified source of MC. • MEC/MD: (See Figure A-5-13) - *Non-MEC/MD Hazard Areas.* Receptors are potentially present but pathways are considered incomplete because there is no source and exposure routes are incomplete. However, note that no conclusions can be drawn about the presence or absence of MEC or MD in the minor excluded portions of MRS-2 denied access by NPS. - *MEC/MD Hazard Area-2A.* MEC/MD may present on the surface and in the subsurface soil. Receptors are potentially present, pathways are considered complete, and exposure routes are considered complete (excluding non-intrusive activities in the subsurface soil).

Table 5-9c. Revised Conceptual Site Model for MRS-3

Profile Type	Site Characterization
Facility Profile	**Location and Area:** • No change from Table 3-1c. • RI findings indicate that there are two MEC/MD Hazard Areas within MRS-3. - MEC/MD Hazard Area-3A is located in the central-western portion of MRS-3 and is 0.92 acres in total area. - MEC/MD Hazard Area-3B is located in the southwestern portion of MRS-3 and is 1.07 acres in total area.
	Structures: • No change from Table 3-1c. • There are no structures within or near MEC/MD Hazard Area-3A or 3B.
	Boundaries: • No change from Table 3-1c. • MEC/MD Hazard Area-3A is approximately bounded on all sides by woodlands. • MEC/MD Hazard Area-3B is approximately bounded to the north, east, and west by woodlands, and to the south by the road and an NPS excluded area.
	Security: • No change from Table 3-1c. • MEC/MD Hazard Areas-3A and 3B are partially covered by dense vegetation (woody and herbaceous), which naturally limits access to parts of the area; however, the road goes through the southern portion of 3B.
	Utilities: • No change from Table 3-1c. • There are no utilities within MEC/MD Hazard Area-3A or 3B.
Physical Profile	**Topography:** • No change from Table 3-1c. • Dunal topography is present on MEC/MD Hazard Areas-3A and 3B with a slight elevation increase moving westward.
	Vegetation: • No change from Table 3-1c. • Similar vegetation can be found within MEC/MD Hazard Areas-3A or 3B.
	Wetlands: • No change from Table 3-1c. • There are no wetlands located within MEC/MD Hazard Area-3A or 3B.
	Soil: • No change from Table 3-1c. • Similar soils can be found within MEC/MD Hazard Areas-3A and 3B.
	Hydrology: • No change from Table 3-1c. • There are no surface water bodies within or near MEC/MD Hazard Areas-3A and 3B.
	Hydrogeology/Geology: • No change from Table 3-1c.
Land Use and Exposure	**Current Land Use:** • No change from Table 3-1c.

Table 5-9c. Revised Conceptual Site Model for MRS-3	
Profile Type	**Site Characterization**
Profile	**Cultural, Archaeological and Historical Resources:** • No change from Table 3-1c.
	Current Potential Human Receptors: • No change from Table 3-1c.
	Potential Future Land Use: • No change from Table 3-1c.
	Potential Future Human Receptors: • No change from Table 3-1c.
Ecological Profile	**Degree of Disturbance:** • No change from Table 3-1c.
	Habitat Types: • No change from Table 3-1c.
	Current Potential Ecological Receptors: • No change from Table 3-1c.
Munitions Release Profile	**Munitions Types:** • MEC/MD Hazard Area-3A. Two MD items were found; no MEC items were found previously or during the RI. • MEC/MD Hazard Area-3B. Three MD items were found; no MEC items were found previously or during the RI.
	Release Mechanisms: • No change from Table 3-1c.
	MEC Density: • Average MEC density for MEC/MD Hazard Area-3A is 3.261 MEC per acre. • Average MEC density for MEC/MD Hazard Area-3B is 3.413 MEC per acre.
	Associated Munitions Constituents: • Groundwater was assessed as a single exposure unit across all MRSs. Manganese was detected from a well (not within any MRS) installed at 880 ft bgs. Because of this extreme depth, the groundwater sample is not believed to reflect any potential site-related contamination. No MC contaminants were detected above background in any of the four shallow groundwater samples**.** • 1 surface soil sample was collected during the SI and analyzed for explosives and TAL metals, however, the Risk Assessment concludes there are no MC issues • No breached MEC items, bulk explosives, or concentrated MD were found that warranted sampling during the RI. By inference from the approved Work Plan, which did not call for soil sampling unless such conditions were found, there is no source of MC.
	Transport Mechanisms/Migration Routes: • Transport mechanisms and migration routes for MEC, MD, and MC remain the same after the RI.

Table 5-9c. Revised Conceptual Site Model for MRS-3	
Profile Type	**Site Characterization**
	Pathway Analysis: • MC: (See Figure A-5-18) - Within MRS-3, receptors are potentially present; however, exposure routes and migration pathways are considered incomplete for soil and groundwater as there is no identified source of MC and the Risk Assessment concludes there are no MC issues. • MEC/MD: (See Figure A-5-14) - *Non-MEC/MD Hazard Areas.* Receptors are potentially present but pathways are considered incomplete because there is no source and exposure routes are incomplete. - *MEC/MD Hazard Areas-3A and 3B.* MEC/MD may be present on the surface and in the subsurface soil. Receptors are potentially present, pathways are considered complete, and exposure routes are considered complete (excluding non-intrusive activities in the subsurface soil).

Table 5-9d. Revised Conceptual Site Model for MRS-4	
Profile Type	**Site Characterization**
Facility Profile	**Location and Area:** • No change from Table 3-1d. • RI findings indicate that there is one MEC/MD Hazard Area within MRS-4. MEC/MD Hazard Area-4A is located in the central portion of MRS-4, within the impact area of the MRS, and is 5.15 acres in total area.
	Structures: • No change from Table 3-1d. • There are no structures within or near MEC/MD Hazard Area-4A.
	Boundaries: • No change from Table 3-1d. • MEC/MD Hazard Area-4A is approximately bounded on all sides by woodlands within the impact area.
	Security: • No change from Table 3-1d. • MEC/MD Hazard Area-4A is partially covered by dense vegetation (woody and herbaceous), which naturally limits access to parts of the area.
	Utilities: • No change from Table 3-1d. • There are no utilities within MEC/MD Hazard Area-4A.
Physical Profile	**Topography:** • No change from Table 3-1d. • Dunal topography is present on MEC/MD Hazard Area-4A with a slight elevation increase moving westward.
	Vegetation: • No change from Table 3-1d. • Similar vegetation can be found within MEC/MD Hazard Area-4A.
	Wetlands: • There are no wetlands present in MRS-4.
	Soil: • No change from Table 3-1d. • Similar soils can be found within MEC/MD Hazard Area-4A.
	Hydrology: • No change from Table 3-1d. • There are no surface water bodies within or near MEC/MD Hazard Area-4A.
	Hydrogeology/Geology: • No change from Table 3-1d.
Land Use and Exposure Profile	**Current Land Use:** • No change from Table 3-1d.
	Cultural, Archaeological and Historical Resources: • No change from Table 3-1d.
	Current Potential Human Receptors: • No change from Table 3-1d.
	Potential Future Land Use: • No change from Table 3-1d.

Table 5-9d. Revised Conceptual Site Model for MRS-4

Profile Type	Site Characterization
	Potential Future Human Receptors: • No changes are anticipated to the current potential human receptors.
Ecological Profile	**Degree of Disturbance:** • No change from Table 3-1d.
	Habitat Types: • No change from Table 3-1d.
	Current Potential Ecological Receptors: • No change from Table 3-1d.
Munitions Release Profile	**Munitions Types:** • MEC items found in MEC/MD Hazard Area-4A during the RI include a 75 mm shrapnel round and a 3-inch Stokes mortar. In addition, five MD items were found.
	Release Mechanisms: • No change from Table 3-1d. • The MEC and MD were found within the MRS impact area confirming the preliminary CSM of this location (MEC/MD Hazard Area-4A) as a former impact area. • Note that no conclusions can be drawn about the presence or absence of MEC or MD in the areas denied access by NPS in this MRS.
	MEC Density: • Average MEC density for MEC/MD Hazard Area-4A is 5.928 MEC per acre.
	Associated Munitions Constituents: • Groundwater was assessed as a single exposure unit across all MRSs. Manganese was detected from a well (not within any MRS) installed at 880 ft bgs. Because of this extreme depth, the groundwater sample is not believed to reflect any potential site-related contamination. No MC contaminants were detected above background in any of the four shallow groundwater samples. • No breached MEC items, bulk explosives, or concentrated MD were found that warranted sampling during the RI. By inference from the approved Work Plan, which did not call for soil sampling unless such conditions were found, there is no source of MC.
	Transport Mechanisms/Migration Routes: • Transport mechanisms and migration routes for MEC, MD, and MC remain the same after the RI.

Table 5-9d. Revised Conceptual Site Model for MRS-4

Profile Type	Site Characterization
	Pathway Analysis: • MC: (See Figure A-5-18) - Within MRS-4, receptors are potentially present; however, exposure routes and migration pathways are considered incomplete for soil and groundwater as there is no identified source of MC and the Risk Assessment concludes there are no MC issues. • MEC/MD: (See Figure A-5-15). - *Non-MEC/MD Hazard Areas.* Receptors are potentially present but pathways are considered incomplete because there is no source and exposure routes are incomplete. However, note that no conclusions can be drawn about the presence or absence of MEC or MD in the areas denied access by NPS in this MRS. - *MEC/MD Hazard Area-4A.* MEC/MD may be present on the surface and in the subsurface soil. Receptors are potentially present, pathways are considered complete, and exposure routes are considered complete (excluding non-intrusive activities in the subsurface soil).

Table 5-9e. Revised Conceptual Site Model for MRS-5

Profile Type	Site Characterization
Facility Profile	**Location and Area:** • No change from Table 3-1e. • RI findings indicate that there are two MEC/MD Hazard Areas within MRS-5: - MEC/MD Hazard Area-5A is located in the northern portion of MRS-5 and is 3.92 acres in total area. - MEC/MD Hazard Area-5B is located in the east-central portion of MRS-5 and is 2.15 acres in total area.
	Structures: • No change from Table 3-1e. • There are no structures within or near either MEC/MD Hazard Area-5A or 5B.
	Boundaries: • No change from Table 3-1e. • MEC/MD Hazard Areas: - MEC/MD Hazard Area-5A is approximately bounded to the north by MRS-4, to the south by beach and woodlands, to the west by woodlands, and to the east by the beach dunes. - MEC/MD Hazard Area-5B is approximately bounded on the north and south by beach and woodlands, to the west by woodlands, and to the east by beach.
	Security: • No change from Table 3-1e. • MEC/MD Hazard Areas-5A and 5B are partially covered by dense vegetation (woody and herbaceous), which naturally limits access to parts of the area. However, beach-goers have open access to 5B.
	Utilities: • No change from Table 3-1e. • There are no utilities within or near either MEC/MD Hazard Area-5A or 5B.
Physical Profile	**Topography:** • No change from Table 3-1e. • Dunal topography is present on both MEC/MD Hazard Areas with a slight elevation increase moving westward.
	Vegetation: • No change from Table 3-1e. • Similar vegetation can be found within MEC/MD Hazard Areas-5A and 5B.
	Wetlands: • No change from Table 3-1e. • No wetlands are located within MEC/MD Hazard Area-5A or 5B.
	Soil: • No change from Table 3-1e. • Similar soils can be found within MEC/MD Hazard Areas-5A and 5B.
	Hydrology: • No change from Table 3-1e. • There are no surface water bodies within MEC/MD Hazard Area-5A. MEC/MD Hazard Area-5B essentially borders the Atlantic Ocean on the east.
	Hydrogeology/Geology: • No change from Table 3-1e.

Table 5-9e. Revised Conceptual Site Model for MRS-5	
Profile Type	**Site Characterization**
Land Use and Exposure Profile	**Current Land Use:** • No change from Table 3-1e.
	Cultural, Archaeological and Historical Resources: • No change from Table 3-1e.
	Current Potential Human Receptors: • No change from Table 3-1e.
	Potential Future Land Use: • No change from Table 3-1e.
	Potential Future Human Receptors: • No changes are anticipated to the current potential human receptors.
Ecological Profile	**Degree of Disturbance:** • No change from Table 3-1e.
	Habitat Types: • No change from Table 3-1e.
	Current Potential Ecological Receptors: • No change from Table 3-1e.
Munitions Release Profile	**Munitions Types:** • The following MEC and MD were found during the RI: - MEC/MD Hazard Area-5A. Four MD items; no MEC items found previously or during the RI. - MEC/MD Hazard Area-5B. One MEC, 4.5 inch, Mark V British armor-piercing, high explosive (APHE) round with a base fuze. No MD found during the RI.
	Release Mechanisms: • No change from Table 3-1e. • Note that no conclusions can be drawn about the presence or absence of MEC or MD in the areas denied access by NPS in this MRS.
	MEC Density: • Average MEC density for MEC/MD Hazard Area-5A is 1.499 MEC per acre. • Average MEC density for MEC/MD Hazard Area-5B is 8.231 MEC per acre
	Associated Munitions Constituents: • Groundwater was assessed as a single exposure unit across all MRSs. Manganese was detected from a well (not within any MRS) installed at 880 ft bgs. Because of this extreme depth, the groundwater sample is not thought to reflect any potential site-related contamination. No MC contaminants were detected above background in any of the four shallow groundwater samples. • 5 surface soil samples were collected during the SI and analyzed for explosives and TAL metals; however, the Risk Assessment concludes there are no MC issues. • No 2006 SI soil samples were collected from the area now designated as MEC/MD Hazard Area-5A. Soil data from a single sample collected in MEC/MD Hazard Area-5B during the 2006 SI showed all metals within background range. • No breached MEC items, bulk explosives, or concentrated MD were found that warranted sampling during the RI. By inference from the approved Work Plan, which did not call for soil sampling unless such conditions were found, there is no source of MC.

Table 5-9e. Revised Conceptual Site Model for MRS-5

Profile Type	Site Characterization
	• Surface water and sediment samples were collected from the Nike Pond. No explosives compounds were found above the detection limit in any of the surface water or sediment samples. Arsenic, manganese, and thallium concentrations were found at levels higher than the screening level in the surface water samples, and thallium concentrations were found at levels higher than the screening level in the sediment samples, but the Risk Assessment concludes there are no MC issues.
	Transport Mechanisms/Migration Routes: • Transport mechanisms and migration routes for MEC, MD, and MC remain the same after the RI.
	Pathway Analysis: • MC: (See Figure A-5-20) - For MRS-5, receptors are potentially present; however, exposure routes and migration pathways are considered incomplete for soil and groundwater as there is no identified source of MC. Exposure routes are considered complete and migration pathways complete for surface water and sediment, however, the Risk Assessment concludes there are no MC issues. • MEC/MD: (See Figure A-5-21) - *Non-MEC/MD Hazard Areas.* Receptors are potentially present but pathways are considered incomplete because there is no source and exposure routes are incomplete. However, note that no conclusions can be drawn about the presence or absence of MEC or MD in the areas denied access by NPS. - *MEC/MD Hazard Area-5A.* MEC may be present and MD is present on the surface and in the subsurface soil. Receptors are potentially present, pathways are complete, and exposure routes are complete (excluding non-intrusive activities in the subsurface soil). - *MEC/MD Hazard Area-5B.* MEC is present and MD may be present on the surface and in the subsurface soil. Receptors are potentially present, pathways are complete, and exposure routes are complete (excluding non-intrusive activities in the subsurface soil).

Table 5-9f. Revised Conceptual Site Model for MRS-6 and MRS-7	
Profile Type	**Site Characterization**
Facility Profile	**Location and Area:** • No change from Tables 3-1f and 3-1g. • RI findings indicate there are no MEC/MD Hazard Areas within MRS-6 or 7.
	Structures: • No change from Tables 3-1f and 3-1g.
	Boundaries: • No change from Tables 3-1f and 3-1g.
	Security: • No change from Tables 3-1f and 3-1g.
	Utilities: • No change from Tables 3-1f and 3-1g.
Physical Profile	**Topography:** • No change from Tables 3-1f and 3-1g.
	Vegetation: • No change from Tables 3-1f and 3-1g.
	Wetlands: • There are no wetlands in MRS-6. • There are wetlands in the eastern, northwest and southwest portions of the MRS-7.
	Soil: • No change from Tables 3-1f and 3-1g.
	Hydrology: • No change from Tables 3-1f and 3-1g.
	Hydrogeology/Geology: • No change from Tables 3-1f and 3-1g.
Land Use and Exposure Profile	**Current Land Use:** • No change from Tables 3-1f and 3-1g.
	Cultural, Archaeological and Historical Resources: • No change from Tables 3-1f and 3-1g.
	Current Potential Human Receptors: • No change from Tables 3-1f and 3-1g.
	Potential Future Land Use: • No change from Tables 3-1f and 3-1g.
	Potential Future Human Receptors: • No change from Tables 3-1f and 3-1g.
Ecological Profile	**Degree of Disturbance:** • No change from Tables 3-1f and 3-1g.
	Habitat Types: • No change from Tables 3-1f and 3-1g.
	Current Potential Ecological Receptors: • No change from Tables 3-1f and 3-1g.
Munitions Release Profile	**Munitions Types:** • No MEC or MD was found during the RI in MRS-6 and 7.

Table 5-9f. Revised Conceptual Site Model for MRS-6 and MRS-7

Profile Type	Site Characterization
	Release Mechanisms: • No change from Tables 3-1f and 3-1g. • Note that due to significant NPS excluded acreage in MRS-7 (and minor portions of MRS-6), no conclusions can be drawn about the presence or absence of MEC or MD in the areas denied access by NPS.
	MEC and MD Density: • No MEC or MD was found during the RI in MRS-6 or 7.
	Associated Munitions Constituents: • Groundwater was assessed as a single exposure unit across all MRSs. Manganese was detected from a well (not within any MRS) installed at 880 ft bgs. Because of this extreme depth, the groundwater sample is not believed to reflect any potential site-related contamination. No MC contaminants were detected above background in any of the four shallow groundwater samples**.** • 5 surface soil samples were collected during the SI and analyzed for explosives and TAL metals; however, the Risk Assessment concludes there are no MC issues. • No breached MEC items, bulk explosives, or concentrated MD were found that warranted sampling of MRS-6 during the RI. By inference from the approved Work Plan, which did not call for soil sampling unless such conditions were found, there is no source of MC. • For the RI, 21 surface soil samples were collected from the Livens Area (MRS-7) and analyzed for metals and explosives. No explosives compounds were detected. No metals were found at levels inconsistent with background concentrations, and the Risk Assessment concludes there are no MC issues.
	Transport Mechanisms/Migration Routes: • Transport mechanisms and migration routes for MEC, MD, and MC remain the same after the RI.
	Pathway Analysis: • MC: (See Figure A-5-18) - Within MRS-6 and 7, receptors are potentially present; however, exposure routes and migration pathways are considered incomplete for soil and groundwater as there is no identified source of MC and the Risk Assessment concludes there are no MC issues. • MEC/MD: (See Figure A-5-17) - Receptors are potentially present but pathways are considered incomplete because there is no source and exposure routes are incomplete. However, note that due to significant NPS excluded acreage in MRS-7 (and minor portions of MRS-6), no conclusions can be drawn about the presence or absence of MEC or MD in the areas denied access by NPS.

Table 5-9g. Revised Conceptual Site Model for MRS-8

Profile Type	Site Characterization
Facility Profile	**Location and Area:** • No change from Table 3-1h. • RI findings indicate that there are no MEC/MD Hazard Areas within MRS-8.
	Boundaries: • No change from Table 3-1h.
	Security: • No change from Table 3-1h.
Physical Profile	**Hydrology:** • No change from Table 3-1h.
	Hydrogeology: • No change from Table 3-1h.
Land Use and Exposure Profile	**Current Land Use:** • No change from Table 3-1h.
	Cultural, Archaeological and Historical Resources: • No change from Table 3-1h.
	Current Potential Human Receptors: • No change from Table 3-1h.
	Potential Future Land Use: • No change from Table 3-1h.
	Potential Future Human Receptors: • No change from Table 3-1h.
Ecological Profile	**Degree of Disturbance:** • No change from Table 3-1h.
	Habitat Types: • No change from Table 3-1h.
	Current Potential Ecological Receptors: • No change from Table 3-1h.
Munitions Release Profile	**Munitions Types:** • No MEC or MD was found during the RI in MRS-8.
	Release Mechanisms: • No change from Table 3-1h.
	MEC/MD Density: • No MEC or MD was found during the RI in MRS-8.
	Associated Munitions Constituents: • No breached MEC items, bulk explosives, or concentrated MD were found that warranted sampling during the RI. By inference from the approved Work Plan, which did not call for soil sampling unless such conditions were found, there is no source of MC.
	Transport Mechanisms/Migration Routes: • Transport mechanisms and migration routes for MEC, MD, and MC remain the same after the RI.

Table 5-9g. Revised Conceptual Site Model for MRS-8	
Profile Type	**Site Characterization**
	Pathway Analysis: • MC: (See Figure A-5-21) - For MRS-8, receptors are potentially present; however, exposure routes and migration pathways are considered incomplete. • MEC/MD: (See Figure A-5-17) - Receptors are potentially present but pathways are considered incomplete because there is no source and exposure routes are incomplete.

5.5 MEC or DGM UNCERTAINTY

There is uncertainty in the detection of MEC or MD due to the limitations of the geophysical detectors used. The G-858, used for the terrestrial investigation, can detect ferrous objects to various depths depending on size. For example, a 37mm round can be detected at a depth of approximately 0.4 m or less, or a 155 mm round can be detected at a depth of approximately 1.7m or less (equation on Table 8-3, EM 1110-1-4009), meaning that small items at depth are more likely to be left in the ground. The G-882, used for the marine investigation, is conceptually similar, although the fact that this sensor is generally some distance above the ocean bottom makes its effective detection depth less than the G-858.

There is uncertainty in the detection capability due to the transect spacing design. The transects are designed to detect impact areas of one half the diameter of the impact areas that defined the extent of each MRS. If smaller impact areas were associated with Fort Hancock activities, they may not have been detected (i.e., if the impact area would be small enough to fit between transects).

There is uncertainty in the results of MEC or MD density as calculated with UXO Estimator software. The calculated average density and density at 95% confidence are inversely and exponentially related to the area investigated. For example, in a hypothetical area of investigation (such as a cluster) of 5 acres, where one MEC item was found, with DGM coverage of 0.25, 0.5, or 1 acre, the average MEC density (MEC/acre) would be 7.8, 3.8, or 1.8, while the MEC density at 95% confidence would be 18.4, 9.0, or 4.2. The fact that DGM coverage in certain clusters was low due to restrictions on vegetation removal imposed by NPS led to reported densities being somewhat higher than they otherwise would have been. However, this was mitigated to the extent practical, by supplementing DGM coverage with mag & dig methods and other procedures discussed in Section 5.1

There is uncertainty associated with incomplete historical records of military operations. It is not known with complete certainty exactly what munitions were fired, where they were fired from, and where they were fired to. There were many anecdotal descriptions based on recollections of various NPS employees; however, in many cases this information could not be confirmed.

Finally, no conclusions can be made about the presence or absence of MEC and MD in the NPS excluded areas.

6.0 BASELINE RISK ASSESSMENT FOR MC

The baseline risk assessment (BLRA) includes a quantitative human health risk assessment (HHRA) and screening level ecological risk assessment (SLERA). The HHRA and SLERA were prepared in accordance with USACE and USEPA guidance. The risk assessment approach and results are discussed below.

6.1 Data used in the BLRA

In addition to the data collected during the RI, the BLRA included results for historical SI samples collected from the areas investigated during the RI. The SI and RI data sets used for each environmental medium is discussed below.

6.1.1 Soil

As discussed in Section 4.2.1.2, 21 discrete surface soil samples were collected from MRS-7, the Livens Discovery Area. No other discrete soil samples were collected during the RI. The SI included collection of discrete surface soil samples from MRS-1, MRS-3, MRS-5, MRS-6, MRS-7, and the B003 Area (previously identified in the EE/CA as an ordnance disposal area located in MRS-1). Because the SI data indicate the presence of elevated metals concentrations in B003 but not throughout the remainder of MRS-1, B003 was treated as its own exposure area for the BLRA. The historical samples were incorporated into the BLRA data set. Including both the SI and RI samples, the soil data set for each MRS consisted of:

- MRS-1: 8 surface soil samples collected in 2006 during the SI.
- MRS-3: 1 surface soil sample collected in 2006 as part of the SI.
- MRS-5: 5 surface soil samples collected in 2006 during the SI.
- MRS-6: 5 surface soil samples collected in 2006 during the SI.
- MRS-7: 5 grab surface soil samples collected in 2006 as part of the SI (biased to stained soils or runoff areas), and 21 surface soil samples collected in 2011 for the RI.
- B003: 3 surface soil samples collected in 2006 as part of the SI.

The SI samples were analyzed for explosives and target analyte list (TAL) metals. The RI samples were analyzed for explosives and select metals.

No samples were collected in MRS-2, MRS-4, and MRS-8, because no visible areas of breached MEC, evidence of energetics, or significant MD were encountered (per the approved Work Plan approach and sampling DQOs). Therefore, risk characterization (Section 6.2.3) was not performed for these MRSs.

6.1.2 Groundwater

The groundwater dataset for the HHRA consists of five samples collected in 2011 as part of the RI. The samples were analyzed for explosives and select metals. This single data set was used to represent groundwater conditions across all the MRSs.

6.1.3 Surface Water and Sediment

As described in Section 4.2.2, the RI included collection of surface water and sediment samples from three locations in Nike Pond, located in MRS-5. The sediment samples were collected from two intervals: 0 – 6 inches deep; and 6 – 12 inches deep. All of the RI samples were analyzed for explosives and select metals. The surface water and sediment data sets also included the single surface water sample and two sediment samples collected during the SI. The SI samples were analyzed for explosives and TAL metals.

6.1.4 Incremental Samples

As described in Section 4.2.1, samples associated with MEC BIP activities were collected using incremental sampling (IS) methodology. BIP samples were collected to determine if MC was released during detonation of found items. Because these samples were composites, they were not included in the quantitative BLRA. Instead, their analytical results were evaluated qualitatively with respect to potential threats to human health and the environment. The incremental sample data set consists of:

- MRS-1: 1 pre-detonation and 3 post-detonation samples;
- MRS-2: 1 post-detonation sample; and
- MRS-5: 2 post-detonation samples.

6.2 Human Health Evaluation

6.2.1 Exposure Assessment

6.2.1.1 Exposure Setting and Conceptual Site Model

Section 2.1.7 describes the current demographics and land use at Fort Hancock. Based on this information, the potential exposure routes for each MRS were selected. Because the investigation did not include volatile compounds, the inhalation of volatilized compounds was not identified as a complete exposure pathway. For all MRSs, the potential exposure media and associated exposure routes are listed below.

- Soil: direct contact with surface soil (ingestion, dermal contact); inhalation via the soil-to-air pathway;
- Sediment (MRS-5 only): direct contact (ingestion, dermal contact);
- Surface water (MRS-5 only): direct contact (ingestion, dermal contact); and
- Groundwater: direct contact (ingestion, dermal contact).

Recreational fishing occurs along the beaches at Sandy Hook, but does not occur at the Nike Pond. For this reason, fish consumption was not identified as a potentially complete exposure pathway for human receptors.

Currently, the shallow groundwater at Fort Hancock is not a potable water source. Due to tidal influence, the shallow groundwater at Fort Hancock is not of potable quality. For this reason, consideration of the shallow groundwater as a hypothetical future potable water source is conservative.

If an excavation, such as that for a utility trench, were to intersect the water table, the construction worker could be incidentally exposed to groundwater. Because of Occupational Safety and Health Administration requirements regarding work in excavations with water seepages, it is likely that the construction worker would experience a negligible exposure. For this reason, the construction worker's incidental exposure to groundwater was not quantitatively evaluated in the BLRA.

6.2.1.2 Receptors

Fort Hancock, part of the Gateway National Recreation Area, receives many visitors year-round with the majority visiting in the summer months to swim, hike, fish, and visit the historic batteries (Alion, 2007). The Sandy Hook peninsula includes full-time and seasonal residences, a school, a day care center, and facilities owned by NPS, the NJMSC, NOAA's National Marine Fisheries Service and the USCG. None of these facilities is currently within the boundaries of the investigation areas. Current land use for the MRS areas is recreational. In addition, the NPS allows archaeologists to investigate cultural and archaeological resources at Fort Hancock. Based on the current land use, the following receptors were identified:

- Outdoor maintenance worker (represents a NPS ranger who spends the majority of his/her time patrolling the area on foot);
- Adult and child recreational user (represent members of the public who partake in recreational activities at Fort Hancock); and
- Archaeologist (either NPS or other researchers performing studies or investigations).

Substantial portions of the MRSs represent sensitive habitat. Based on these ecological conditions, there are portions of the investigation areas that are unlikely to be developed in the future because they represent sensitive habitat. Regardless, it is assumed that all of the investigation area could be re-developed for future residential use or commercial-type use (e.g., NPS facility). Based on this assumption, future receptors would include hypothetical residents and the construction worker in addition to the outdoor maintenance worker, adult recreational user, child recreational user, and archaeologist.

Nike Pond is located within MRS-5. Originally a natural pond, it has been altered by man. Based on information provided by the NPS historian, the U.S. Army altered the pond during World War II for use in testing small, amphibious "duck" jeeps. Instead of a natural shoreline with a gradual slope into the water, the pond is edged with concrete that acts as a retaining wall. Along the edge, the pond depth is between 3 feet and 5 feet. The concrete nature and depth of the pond would discourage wading or playing along the pond edge by children. There is an actively-used bird blind at the pond that does draw visitors to the pond. Based on these site conditions, potential exposure to surface water and sediment by recreational users is expected to be negligible. Regardless, these exposure routes were considered in the HHRA for the child recreational user and child resident. In addition, there is potential for NPS employees to be exposed to surface water in Nike Pond on an infrequent basis. Once per 10 years, the turtles and eels in Nike Pond are monitored. For these monitoring activities, personnel set traps in the pond and then remove the animals. Because personnel wear waders, exposure to pond sediment is not expected.

6.2.1.3 Screening to Identify Chemicals of Potential Concern

Analytes not detected in any of the samples for a particular medium were not identified as chemicals of potential concern (COPCs) for that medium. The potential uncertainty associated with this approach was evaluated as part of the uncertainty analysis (see Section 6.2.7). In accordance with the Risk Assessment Guidance for Superfund (RAGS) (USEPA, 1989), calcium, magnesium, potassium, and sodium were not identified as COPCs because of their status as essential nutrients. In accordance with USEPA guidance, COPCs were identified through comparison of maximum detected concentrations to risk-based screening levels. Screening levels were obtained from the May 2012 USEPA RSLs and the NJDEP.

For soil, the COPCs were identified by comparing the maximum detected concentration to the USEPA residential soil RSLs (cancer risk = 1E-06, non-cancer hazard quotient [HQ] = 0.1) and the New Jersey Soil Remediation Standards (residential soil). For a given analyte, if the maximum detected concentration was greater than either of these screening values, the chemical was identified as a COPC for soil.

Although the USEPA residential soil RSLs are based on a conservative scenario, the values were not developed to account for the potential inhalation exposure associated with excavation activities. To ensure that potential COPCs for construction workers exposed via the soil-to-air pathway are identified in the screening process, a separate soil-to-air screening was performed for the construction worker. For this screening, potential ambient air concentrations were estimated in accordance with the equations identified in Section 5 of Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA, 2002). The maximum estimated air concentration was compared to the USEPA industrial air RSL (cancer risk = 1E-06, non-cancer HQ = 0.1).

To identify sediment COPCs, the maximum detected concentration was compared to the USEPA residential soil RSLs (cancer risk = 1E-06, non-cancer HQ = 0.1). Because potential exposure to sediment is substantially less than that for residential soil, this screening approach is highly conservative.

To identify the surface water COPCs, the maximum detected concentrations were compared to the USEPA tap water RSLs (cancer risk = 1E-06, non-cancer HQ = 0.1). Because there is limited potential for exposure to surface water in Nike Pond, comparison of the data to concentrations protective of potable water is highly conservative. In addition, the surface water data was compared to the New Jersey Surface Water Quality Standards for human health.

The groundwater detections were compared to the USEPA tap water RSLs (cancer risk = 1E-06, non-cancer HQ = 0.1) to identify the COPCs.

For each MRS and each medium, the COPC screening is presented in RAGS Part D Tables 2.1 through 2.15 (Appendix G-1).

6.2.1.4 Exposure Assumptions

This section identifies the exposure routes that were evaluated for each current and future receptor. The potential exposure routes are summarized in RAGS Part D Table 1 of Appendix G-1. For each receptor, the exposure assumptions (i.e., exposure duration, exposure frequency, etc.) are described below and presented in RAGS Part D Tables 4.1 through 4.20 (Appendix G-1).

The potentially complete exposure routes are:

- Outdoor maintenance worker (current and future) – exposed to surface soil through incidental ingestion, dermal contact, and inhalation of fugitive dust emissions. Default exposure assumptions were obtained from Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA, 2002). Exposed to surface water via dermal contact once per 10 years during turtle and eel monitoring activities. Exposure assumptions were provided by NPS personnel.
- Adult and child recreational users (current and future) – exposed to surface soil through incidental ingestion, dermal contact, and inhalation of fugitive dust emissions. Exposed to surface water and sediment in Nike Pond through incidental ingestion and dermal contact (child recreational user only). Based on the physical pond conditions (concrete-walled such that there is no slope, but an immediate 3-foot to 5-foot drop), it is unlikely that the recreational user would spend much time in Nike Pond. Site-specific exposure assumptions based on professional judgment considering reasonable seasonal recreational use.
- Archaeologist (current and future) – exposed to surface soil through incidental ingestion, dermal contact, and inhalation of fugitive dust emissions. Based on information from the NPS, this receptor is exposed in a similar manner as a construction worker. However, because the archaeologist does not generate significant dust emissions, the ambient air concentrations for the soil-to-air pathway were estimated with the equations for non-intrusive activities.
- Resident (future) – exposed to future surface soil through incidental ingestion, dermal contact, and inhalation of fugitive dust emissions. Exposed to shallow groundwater through ingestion and dermal contact. Default exposure assumptions from USEPA guidance. Child resident also assumed to be exposed to surface water and sediment in Nike Pond through recreational use of Fort Hancock. The resident was evaluated as adult and child for non-cancer hazards and age-adjusted for cancer risk.
- Construction worker (future) – exposed to surface soil and subsurface soil through incidental ingestion, dermal contact, and inhalation of fugitive dust emissions. Based on an assumed depth to groundwater of 4 feet, excavations are not expected to be deeper than 4 feet. Potential incidental exposure to shallow groundwater assumed to be negligible. Default exposure assumptions were obtained from Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA, 2002).

6.2.1.5 Calculation of Chronic Daily Intake

The different equations used for calculating chemical intake are provided in the RAGS Part D Tables 4.1 through 4.20 (Appendix G-1).

Consistent with RAGS, the exposure point concentrations are calculated upper confidence levels (UCLs) of the expected value of the data set. For data sets with five or more detections, the USEPA software ProUCL 4.1 was used to calculate a UCL value. For data sets with four or fewer detections, the maximum detected concentration was the exposure point concentration, but the risk characterization also included a central tendency evaluation (CTE) if the maximum detection resulted in unacceptable health threats. The CTE was based on the median detection.

To evaluate the soil-to-air pathway, it was necessary to estimate the potential ambient air concentration. For this estimate, a Particulate Emission Factor (PEF) was applied to the UCL calculated for the soil data. For non-intrusive activities, the PEF was the default value of 1.36 x 10^9 m^3/kg (USEPA, 2002). For scenarios involving excavation activities, the PEF was calculated in accordance with the equations in Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA, 2002).

The exposure point concentrations (EPCs) are provided in the RAGS Part D Tables 3.1 through 3.9 (Appendix G-1).

6.2.2 Toxicity Assessment

Reference doses, reference concentrations, cancer slope factors, and inhalation unit risks were obtained from various sources, USEPA and non-USEPA, in accordance with the hierarchy outlined in Office of Solid Waste and Emergency Response (OSWER) Directive 9285.7-53 (USEPA, 2003a). The values used for this HHRA are presented in RAGS Part D Tables 5.1, 5.2, 6.1, and 6.2 (Appendix G-1). If a value could not be found in any of the sources listed in this OSWER Directive, the value listed in the RSL tables was used. Dermal reference doses and cancer slope factors were estimated from oral values in accordance with RAGS Part E, Supplemental Guidance for Dermal Risk Assessment (USEPA, 2004).

The potential effects from exposure to lead were evaluated through blood lead models. The USEPA has developed two models for this evaluation: (1) the Integrated Exposure Biokinetic Uptake (IEUBK) model; and (2) the Adult Lead Model (ALM). Children and fetuses are the most sensitive receptors with respect to health effects from lead. IEUBK is used to evaluate children's exposure to lead. The ALM is used to assess exposure to the fetus if the pregnant woman is exposed to lead in soil. The ALM calculates the average soil concentration that will result in a fetal blood lead concentration less than 10 micrograms per deciliter (µg/dL), the value determined by USEPA to be protective. IEUBK considers children's exposure to lead in soil and other media, including water and diet.

6.2.3 Risk Characterization

For a given receptor, cancer risks were calculated for each COPC within each exposure medium, summed across each exposure medium, and summed across all exposure media. This cumulative cancer risk included contributions from both site-related chemicals and chemicals present due to background conditions. The equations for calculating the cancer risk are:

$$\text{(direct contact) ILCR} = \text{Intake (mg/kg/d)} \times \text{CSF (mg/kg/d)}^{-1}$$

and

$$\text{(inhalation) ILCR} = \text{Adjusted Ca (mg/m}^3\text{)} \times \text{IUR (mg/m}^3\text{)}^{-1}$$

Where: ILCR = incremental lifetime cancer risk

CSF = cancer slope factor

Adjusted Ca = air concentration adjusted to account for exposure

IUR = inhalation unit risk

The HQ for each COPC was summed across each exposure medium and all exposure media to provide a total hazard index (HI) for each receptor. For HIs greater than 1, a target organ analysis was performed in order to account for differences in toxic mechanisms among the COPCs. As with the cancer risk calculations, the total and target organ HIs included contributions from background chemicals and site-related chemicals. The equations for calculating the HQs are:

(direct contact) HQ = Intake (mg/kg/d) / RfD (mg/kg/d)

and

(inhalation) HQ = Adjusted Ca (mg/m^3)/RfC (mg/m^3)

Where: HQ = hazard quotient

RfD = reference dose

Adjusted Ca = air concentration adjusted to account for exposure

RfC = reference concentration

To distinguish site-related risks and hazards from background risks and hazards, the cumulative cancer risks, total HIs, and target organ HIs were re-calculated excluding those COPCs determined to be present due to background conditions. For the background evaluation, the results were compared to the NJ urban values (NJDEP, 1993, Table 9) and to the background data collected at Fort Hancock during the SI (Alion, 2007, Table 7-6). An urban land use was selected because Fort Hancock experiences a high traffic volume due to its use as a recreation area and because of its proximity to urban areas. The site-related cancer risk was compared to the USEPA target risk range of 1E-06 to 1E-04. The site-related target organ HIs were compared to a target value of 1. The cancer risks and non-cancer hazards for each MRS are discussed in the subsections below.

6.2.3.1 MRS-1

Arsenic, cobalt, iron, and manganese were identified as soil COPCs for MRS-1. The maximum arsenic concentration, 8.9 mg/kg, was less than the 90th percentile of the NJ background data set (10.9 mg/kg), and the average arsenic concentration, 3.7 mg/kg, was less than the average NJ background value (8.26 mg/kg). All manganese detections were less than the average NJ background value. These comparisons demonstrate that arsenic and manganese at MRS-1 are background constituents.

The NJ background study did not include analysis for iron or cobalt. The maximum iron concentration, 13,000 mg/kg, was less than the maximum Fort Hancock background concentration of 13,200 mg/kg, and the average concentration of 7,350 mg/kg was less than the mean Fort Hancock background concentration of 11,630 mg/kg. The MRS-1 cobalt concentrations, which ranged from 0.15 mg/kg to 1.8 mg/kg with an average detection of 0.77 mg/kg, were consistent with the range of cobalt results reported for the Fort Hancock background samples: 0.3 J – 1.1 mg/kg with a mean value of 0.84 mg/kg. These comparisons indicate that iron and cobalt are also background constituents.

Because all of the soil COPCs were determined to represent background conditions, the only potential risks posed by the site soil are those associated with background conditions. For this reason, a quantitative HHRA was not performed for MRS-1.

6.2.3.2 MRS-3

Four metals were identified as soil COPCs for MRS-3: aluminum, arsenic, iron, and manganese. Background data were not available for aluminum and iron. The arsenic and manganese detections were less than the average NJ background values. Both arsenic and manganese were determined to be naturally occurring.

The NJ background study did not include results for aluminum and iron. The MRS-3 results for these metals were compared to the Fort Hancock background data. The aluminum detection, 1,430 mg/kg, was less than the range of concentrations (1,460 – 2,030 mg/kg) reported for the Fort Hancock background samples. The MRS-3 iron result, 8,220 mg/kg, was on the low end of the concentrations reported for the Fort Hancock background samples (8,120 – 13,200 mg/kg). These comparisons demonstrate that aluminum and iron are background constituents.

Because all of the soil COPCs were determined to represent background conditions, the only potential risks posed by the site soil are those associated with background conditions. For this reason, a quantitative HHRA was not performed for MRS-3.

6.2.3.3 MRS-5

As shown in RAGS Part D Tables 2.5 and 2.6 (Appendix G-1), arsenic, iron, cobalt, and manganese were identified as COPCs for MRS-5 soil. All arsenic and manganese detections were less than the average NJ background values. Both metals were identified as naturally occurring. The NJ background study does not list data for cobalt or iron. The SI included collection of three background surface soil samples. The maximum cobalt detection at MRS-5, 0.9 mg/kg, was within the range of detections (0.3 J – 1.1 mg/kg) for the Fort Hancock background samples. Similarly, the maximum MRS-5 iron detection, 11,300 mg/kg, was less than the maximum iron detection of 13,200 mg/kg reported for the Fort Hancock background samples. These comparisons indicate that all of the soil COPCs for MRS-5 reflect background conditions. Thus, any potential effects associated with these COPCs would represent naturally occurring risks. For this reason, the health threats associated with soil at MRS-5 were not quantified. Instead, the HHRA focused on exposure to the sediment and surface water in Nike Pond, which is located within MRS-5.

The non-cancer HI and cancer risk calculations for Nike Pond are presented in RAGS Part D Tables 7.1 through 7.3 and 8.1 through 8.3 of Appendix G-1, and are summarized in RAGS Part D Tables 9.1 through 9.4.

- Current/future outdoor maintenance worker: For surface water exposure, the total cancer risk was estimated to be 7E-10, and the total HI was estimated to be 0.0009. The cancer risk was less than the acceptable EPA risk range of 1E-06 to 1E-04 and the total HI was less than 1.
- Current/future child recreational user: Exposure to surface water resulted in a cancer risk of 1E-07 and HI of 0.004. For exposure to sediment, the cancer risk was estimated to be 1E-07 and the HI to be 0.007. For all media combined, the total cancer risk was estimated to be 2E-07 and the total HI was estimated to be 0.01. The cancer risk was less than the acceptable EPA risk range of 1E-06 to 1E-04 and the total HI did not exceed 1.
- Future child resident: Because cancer risks were calculated for the age-adjusted resident, cancer risks were not quantified for the child resident. The HIs were 0.004 for exposure

to surface water, 0.007 for exposure to sediment, and, 3 for exposure to groundwater. Across all media, the total HI was 3. The HIs for skin (3) and the vascular system (3) were greater than 1 due to arsenic in groundwater.

- Future age-adjusted resident: The cancer risks were estimated to be 1E-07 for exposure to surface water, 1E-07 for exposure to sediment, and 3E-04 for exposure to groundwater. Across all media, the cumulative cancer risk was 3E-04. Arsenic in groundwater is the risk driver.

In summary, the chemicals detected in the Nike Pond surface water and sediment samples do not pose a threat to human health under current and potential future conditions. In addition, of the four sediment COPCs (arsenic, iron, thallium, and vanadium), the results for arsenic and thallium were not indicative of contamination. Background sediment data are not available. However, because sediment represents eroded soil, a qualitative comparison of the analytical results to soil background levels can indicate whether a metal reflects likely background conditions. The maximum arsenic concentration, 7.7 mg/kg, was consistent with the NJ background values for soil, suggesting that this metal is naturally occurring. The maximum thallium detection, 0.54 mg/kg, was less than the maximum and mean concentrations for the Fort Hancock background samples, suggesting that thallium is also naturally occurring.

Any potential risks identified for MRS-5 were due to arsenic in groundwater. The risks associated with use of the groundwater as a potable water supply are discussed in Section 6.2.3.7.

6.2.3.4 MRS-6

Similar to MRS-5, the COPCs identified for the MRS-6 soil were arsenic, iron, cobalt, and manganese. All arsenic and manganese detections were less than the average NJ background concentrations. As described for MRS-5, the MRS-6 cobalt and iron results were compared to the Fort Hancock background data collected during the SI. The maximum cobalt detection of 0.91 mg/kg was within the range of Fort Hancock background results (0.3 J - 1.1 mg/kg). The maximum MRS-6 iron detection, 6,940 mg/kg, was less than the range of iron concentrations (8,120 – 13,200 mg/kg) reported for the SI background samples. This comparison provides no evidence that a release occurred at MRS-6. This conclusion is supported by the lack of MD and breached MEC items found at the site. Because the data indicate that a release did not occur at MRS-6, a quantitative risk assessment was not performed for this site.

6.2.3.5 MRS-7

Arsenic, iron, manganese, and thallium were identified as the only soil COPCs. Comparison of their concentrations to background values is presented below.

- Arsenic: the maximum detection of 11.5 mg/kg was approximately equal to the 90^{th} percentile of the NJ background data set. In addition, the 95% UCL of the soil data set, 4.2 mg/kg, was less than the average NJ background concentration (8.26 mg/kg). Arsenic was identified as naturally occurring.

- Iron: the maximum detection, 6,690 mg/kg, was less than the range of concentrations (8,120 – 13,200 mg/kg) reported for the Fort Hancock background samples. Iron was identified as naturally occurring.

- Manganese: all detections were less than the average NJ background concentration. Manganese was identified as naturally occurring.
- Thallium: the maximum thallium detection, 0.76 mg/kg, was approximately equal to the maximum NJ background value of 0.46 mg/kg and was less than the maximum concentration reported for the Fort Hancock background samples. In addition, thallium was detected in only 6 of 26 samples, suggesting limited presence at the site. Thallium was identified as naturally occurring.

As described above, all soil COPCs were determined to be naturally occurring. Thus, any potential health effects associated with exposure to the soil at MRS-7 would represent natural conditions at Fort Hancock. For this reason, a quantitative risk assessment was not performed for MRS-7.

6.2.3.6 B003 Area

In the B003 Area, three biased surface soil samples were collected in 2006 for the SI. The source of the contamination (described below) in one of those samples is not known. The sample (FHK-NP-SS-06-03) is approximately 150 ft south of the B003 grid that contained MEC and MD. Figure A-5-5 delineates a 2.2 acre potential MC area of concern footprint that includes the three sample locations with the B003 grid at its center.

Based on the three soil samples collected within the B003 Area, 10 metals were identified as soil COPCs for the B003 Area: aluminum, antimony, arsenic, barium, cobalt, copper, iron, lead, manganese, and thallium. Each of these metals is compared to background concentrations below.

- Aluminum: The maximum aluminum detection, 1,790 mg/kg, was within the range of aluminum concentrations, 1,460 – 2,030 mg/kg, reported for the Fort Hancock background samples. Aluminum was identified as a background constituent.
- Antimony: The maximum antimony concentration, 26.4 mg/kg, was greater than the maximum NJ background value and the Fort Hancock background concentrations. Antimony was identified as a potential contaminant.
- Arsenic: The maximum arsenic concentration, 114 mg/kg, was greater than the maximum NJ background value and the Fort Hancock background concentrations. Arsenic was identified as a potential contaminant.
- Barium: The NJ background study did not report barium concentrations. The maximum barium concentration, 149 mg/kg, was greater than the maximum Fort Hancock background concentration, 20.1 mg/kg. Barium was identified as a potential contaminant.
- Cobalt: The range of cobalt detections, 1.5 – 3.1 mg/kg, was greater than the range of cobalt values, 0.3 J – 1.1 mg/kg, reported for the Fort Hancock background samples. Cobalt was identified as a potential contaminant.
- Copper: The maximum copper concentration, 384 mg/kg, was greater than the maximum NJ background value and the Fort Hancock background concentrations. Copper was identified as a potential contaminant.

- Iron: The maximum iron concentration, 48,200 mg/kg, was greater than the Fort Hancock background concentrations. Iron was identified as a potential contaminant.
- Lead: The maximum lead concentration, 2,180 mg/kg, was greater than the maximum NJ background value and the Fort Hancock background concentrations. Lead was identified as a potential contaminant.
- Manganese: All manganese detections were less than the average NJ background concentration. Manganese was identified as a background constituent.
- Thallium: Thallium was detected in one sample at a concentration of 6.5 mg/kg. This detection was greater than the NJ background values and the Fort Hancock background concentrations. Thallium was identified as a potential contaminant.

The non-cancer HI and cancer risk calculations for B003 are presented in RAGS Part D Tables 7.4 through 7.13 and 8.4 through 8.11 of Appendix G-1, and are summarized in RAGS Part D Tables 9.5 through 9.18. The risks are discussed by receptor below.

- Current/future outdoor maintenance worker: The total cancer risk, 6E-05, was within the target risk range (1E-06 – 1E-04). The total HI was equal to 0.6, indicating no potential for non-cancer adverse effects. Approximately 86% of the cancer risk was due to arsenic contamination.
- Current/future archeologist: The total cancer risk, 9E-06, was within the target risk range. Approximately 86% of the cancer risk was due to arsenic contamination. The total HI was 2. Because this value exceeded 1, a target organ analysis was performed. All target organ HIs were less than or equal to 1, indicating no potential for non-cancer adverse effects.
- Current future child recreational user: The total cancer risk, 2E-05, was within the target risk range. Approximately 86% of the cancer risk was due to arsenic contamination. The total HI was 0.6, indicating no potential for non-cancer adverse effects.
- Current/future adult recreational user: The total cancer risk, 1E-05, was within the target risk range. Approximately 86% of the cancer risk was due to arsenic contamination. The total HI, 0.07, was less than 1, indicating no potential for non-cancer adverse effects.
- Future construction worker: The total cancer risk, 1E-05, was within the target risk range. The total HI, 6, was greater than 1. On a target organ basis, HIs for vascular system (4) and development (3) were greater than 1. The primary risk driver was arsenic. Approximately 86% of the risk was due to arsenic contamination.
- Future child resident: Because cancer risks were quantified for age-adjusted resident, cancer risk calculations were not performed for the child resident. The HI was estimated to be 7 for exposure to soil and 3 for exposure to groundwater. Across all media, the total HI was 11. On a target organ basis, the HI for skin (8) and the vascular system (8) was greater than 1. Arsenic in soil contributed a HQ of 5 to the total skin/vascular system HI, and arsenic in groundwater contributed a HQ of 3. Approximately 86% of the soil HQ was due to arsenic contamination.

- Future adult resident: Because cancer risks were quantified for age-adjusted resident, cancer risk calculations were not performed for the adult resident. Exposure to soil resulted in a HI of 0.8, and exposure to groundwater resulted in a HI of 1. For the adult resident's exposure to both soil and groundwater, the total HI was estimated to be 2. On a target organ basis, HI for skin (2) and vascular system (2) were greater than 1. The primary risk driver was arsenic in soil (HQ of 0.6) and groundwater (HQ of 1). Approximately 86% of the soil HQ was due to arsenic contamination.
- Future age-adjusted resident: Exposure to soil resulted in a cancer risk of 3E-04, and exposure to groundwater also resulted in a cancer risk of 3E-04. The total cancer risk for the age-adjusted resident was estimated to be 6E-04. The primary risk driver was arsenic in soil (3E-04) and groundwater (3E-04). Approximately 86% of the soil cancer risk was due to arsenic contamination.

Current and potential future site conditions do not pose a threat to the outdoor maintenance worker, archaeologist, child recreational user, and adult recreational user.

Because of the limited number of samples collected at B003, the above risks were calculated using the maximum detected concentrations. Also, all of the maximum concentrations listed for the metals determined to be potential contaminants above were from the same soil sample (FHK-NP-SS-06-03). This approach is extremely conservative. Accordingly, the soil risks for the construction worker and future resident were re-calculated using the median detected concentration as the exposure point concentration for each COPC. These calculations are presented in Tables 7.11 through 7.13, 8.10 through 8.11, and 9.14 through 9.18 of Appendix G-1.

The CTE evaluation for the construction worker decreased the cancer risk to 8E-07 and the total HI to 1. Under the CTE conditions, the B003 soil does not pose a threat to the construction worker.

Use of the CTE exposure point concentrations for both soil and groundwater resulted in a cumulative cancer risk of 1E-04 for the age-adjusted resident, with the majority of the risk (1E-04) from groundwater exposure and a lower risk (2E-05) from soil exposure. The cumulative risk is at the upper end of the target risk range. For soil, all of the risk can be attributed to background arsenic conditions.

For the adult resident, the CTE exposure point concentrations decreased the total HI to 0.7, with groundwater contributing a HI of 0.6 and soil contributing a HI of 0.08. For the child resident, the total CTE HI was 2, with soil contributing a HI of 0.8 and groundwater contributing a HI of 1. On a target organ basis, none of the HIs exceeded 1.

In summary, under the RME exposure scenario, arsenic in soil at B003 could pose a threat to the future construction worker and future resident. Under the CTE scenario, soil does not pose a threat to human health. The potential risks associated with groundwater consumption are discussed in Section 6.2.3.7.

6.2.3.7 Groundwater

The reasonable maximum exposure (RME) potable water scenario resulted in a total HI of 3 for the child resident and 1 for the adult resident, and a cancer risk of 3E-04 for the age-adjusted resident. The risk driver was arsenic. Because arsenic was detected in only four samples, the

RME evaluation was based on the maximum detected concentration. Due to groundwater's transience, it is unlikely that a resident would be exposed to the maximum detected concentration for a 30-year exposure period. For this reason, a CTE evaluation was performed using the median arsenic detection (Tables 7.16 and 8.13 of Appendix G-1). The median arsenic concentration resulted in a cancer risk of 1E-04, and non-cancer HIs less than or equal to 1.

Currently, potable water Fort Hancock is obtained from a deep aquifer approximately 880 feet bgs. Arsenic was not detected in the sample collected from the water supply well (FHRI-PUMP-DW-01). In the four shallow groundwater samples, the arsenic concentration ranged from 4.1 μg/L to 12.5 μg/L. Only the maximum detection was greater than the MCL of 10 μg/L. This maximum detection was reported for a well (GW2E) located within MRS-5 and near (approximately 350 feet northeast) MRS-7. All data for these two MRSs demonstrate that arsenic concentrations in soil reflect background conditions. There is no evidence that arsenic was released to the soil in the vicinity of the well with the maximum detection. In addition, according to a U.S. Geological Survey study (Distribution of Arsenic in the Environment in New Jersey, date unknown), typical arsenic concentrations in groundwater are 2 ug/L, but may occur naturally as high as 50 μg/L. Based on the lack of soil contamination and typical groundwater conditions, it is likely that arsenic in groundwater reflects background conditions, not contamination.

Finally, it should be noted that the shallow groundwater that this well represents is not used for any purpose. Due to its tidally influenced nature, it is unlikely to be used as a potable water supply. For this reason, evaluation of the potable water scenario is overly conservative.

6.2.3.8 Lead

Lead was identified as a COPC for the B003 Area soil. The ALM was used to estimate soil concentrations protective of a fetus whose mother may be exposed while working outside at the B003 Area. The ALM model input and results are shown in Table 1 of Appendix G-1-A. The protective soil concentration was calculated to be 1,120 mg/kg for a worker engaged in contact-intensive activities, such as construction or archeology. The average lead concentration in B003 Area surface soil is 800 mg/kg. This exposure point concentration is less than the protective concentration estimated by the ALM, demonstrating that the site does not pose a threat to human health under these exposure scenarios for adult workers. Because the adult recreational user would experience less exposure than the outdoor maintenance worker or construction worker, the concentrations calculated with the ALM would also be protective of this receptor.

The most conservative exposure scenario is residential use of the site. The IEUBK model is used to assess the potential threat posed by lead under residential land use. As noted earlier, this model considers exposure to lead in multiple media. For soil, the model uses the mean value as the exposure point concentration for soil. The average concentration of B003 Area soil samples was 800 mg/kg.

Other than the soil concentration, all input parameters to the IEUBK model were set to the default values. The model output is presented in Figure G-1 (presented at the end of Appendix G-1). The soil concentration of 800 mg/kg resulted in a geometric mean blood lead concentration of 7.55 µg/dL, with the blood lead concentration for 72.5 percent of the exposed population falling below the target concentration of 10 µg/dL. If at least 95 percent of the exposed population is estimated to have a blood lead concentration less than 10 µg/dL, then site conditions are protective. The IEUBK output demonstrates that lead in soil at B003 Area could pose a threat to children exposed under a residential land use.

Lead also was identified as a COPC in surface water at Nike Pond within MRS-5. The ALM and IEUBK models are not applicable to surface water. For this reason, lead concentrations detected in MRS-5 surface water were evaluated qualitatively. The maximum lead concentration detected in MRS-5 surface water samples is 6.6 µg/L. The most conservative lead screening value used to establish surface water COPCs is 5 µg/L, which is the NJDEP Water Quality Standard. The NJDEP Water Quality Standards are based on a drinking water exposure scenario. The potential exposure to surface water at MRS-5 would be significantly less than that for a drinking water scenario. Since lead was not much higher than the standard, and the significantly lower exposure potential for MRS-5 surface water as compared to a potable water scenario, the lead in the surface water is unlikely to pose a threat to human health.

In summary, as demonstrated by IEUBK results, lead concentrations in B003 Area surface soil could pose a threat to human health. In addition, based on a qualitative evaluation, lead in Nike Pond surface water at MRS-5 does not pose a threat to human health.

6.2.3.9 Incremental Samples

As noted previously, the incremental samples were evaluated qualitatively instead of quantitatively because these samples are composited samples, not discrete samples. The results for each incremental sample were compared to the health-based screening values in the same manner as described for the quantitative HHRA. This screening is presented in Tables 2.16 through 2.29 of Appendix G-1, and is discussed by sample below.

<u>IS Sample FHRI-01-SO-01 – Post-BIP</u>: The arsenic and manganese detections were greater than the health-based screening values, but less than the average NJ background concentrations. Any potential threats associated with this location would be consistent with background conditions.

<u>IS Sample FHRI-01-SO-02 – Post-BIP</u>: The arsenic, manganese, and thallium results exceeded the health-based screening values.

- The arsenic result, 12.7 mg/kg, was slightly greater than the average NJ background value (8.26 mg/kg). The total concentration would result in a cancer risk of approximately 3E-05, with two thirds of the risk (2E-05) attributed to background conditions and one third of the risk (1E-05) associated with potential site contamination.
- The manganese result was less than the average NJ background concentration. Manganese was determined to be naturally occurring.
- The thallium detection, 0.26 mg/kg, was less than the Fort Hancock mean background concentration of 0.64 mg/kg. There is no evidence that thallium was released at this location.

The above comparison indicates that the potential arsenic contamination would contribute little to overall cancer risks. Any potential effects from manganese and thallium would be consistent with background conditions.

<u>IS Sample FHRI-01-SO-03 – Pre-BIP</u>: The arsenic and thallium detections were greater than the health-based screening values. The arsenic concentration was less than the average NJ background value. The thallium result, 0.55 mg/kg, was less than the Fort Hancock mean

background concentration of 0.64 mg/kg. This comparison indicates that any potential risks at this sample location would be consistent with background conditions. In addition, the thallium result was less than the RSL associated with a HQ of 1 (arsenic and thallium affect different target organs).

IS Sample FHRI-01-SO-04 – Post-BIP: The arsenic, manganese, and thallium results were greater than the health-based screening values. The arsenic and manganese concentrations were less than the average NJ background value, indicating that both metals are naturally occurring. The thallium result, 0.5 J mg/kg, was less than the Fort Hancock mean background concentration of 0.64 mg/kg. This comparison indicates that any potential risks at this sample location would be consistent with background conditions. In addition, the thallium result was less than the RSL associated with a HQ of 1 (arsenic and thallium affect different target organs).

IS Sample FHRI-02-SO-01 – Post-BIP: The arsenic, manganese, and thallium results exceeded the health-based screening values. The arsenic and manganese concentrations were less than the average NJ background value, indicating that both metals are naturally occurring. The thallium detection, 0.26 mg/kg, was less than the Fort Hancock mean background concentration of 0.64 mg/kg. This comparison indicates that any potential health threats at this sample location would be consistent with background conditions. It should be noted that the thallium result is less than the RSL associated with a HQ of 1 (arsenic, manganese, and thallium affect different target organs).

IS Sample FHRI-05-SO-01 – Post-BIP: The antimony, arsenic, manganese, and thallium detections were greater than the health-based screening values. The antimony result was greater than NJ background levels, but less than the residential soil RSL associated with a HQ of 1 (antimony does not affect the same target organs as the other metals). Thus, the antimony does not pose a threat to human health.

The arsenic and manganese concentrations were less than the average NJ background value, indicating that both metals are naturally occurring. The thallium result, 0.7 J mg/kg, was slightly greater than the Fort Hancock mean background concentration, but less than the residential soil RSL associated with a HQ of 1. Thallium does not affect the same target organs as the other three metals. Thus, the thallium would not pose a threat to human health.

IS Sample FHRI-05-SO-02 – Post-BIP: The arsenic, manganese, and thallium results exceeded the health-based screening values. The arsenic and manganese concentrations were less than the average NJ background value, indicating that both metals are naturally occurring. The thallium result, 0.5 J mg/kg, was less than the Fort Hancock mean background concentration of 0.64 mg/kg. This comparison indicates that any potential risks at this sample location would be consistent with background conditions. In addition, the thallium result was less than the RSL associated with a HQ of 1 (arsenic and thallium affect different target organs).

In summary, the above qualitative evaluation indicates that any potential health threats associated with the soil at the IS locations would be consistent with background conditions.

6.2.4 Uncertainty Assessment

Conducting a risk assessment requires making a number of assumptions that introduce uncertainty to the risk and hazard estimates. The following sections discuss the uncertainties resulting from chemical analysis, exposure assessment, and toxicity assessment.

6.2.4.1 Chemical Analysis

At any site, it is possible that there are more chemicals present than identified in the sampling and analysis effort. To minimize this potential uncertainty, the analytical suites included all potential contaminants associated with historical operations. In addition, the sample locations were biased to those areas with the greatest potential for contamination as indicated by historical information and the geophysical survey. For these reasons, it is unlikely that significant chemical contamination went undetected. Further, the application of QC throughout the sampling, analysis, and data validation phases reduced uncertainty in the results. Therefore, the chemical identification phase of the risk assessment does not appear to have introduced substantial uncertainty.

While there is limited uncertainty associated with the analytical data, it is possible that the analytical method was not sufficiently sensitive to detect potential contaminants at concentrations that could pose a threat to human health. This potential uncertainty is evaluated by comparison of the reporting limits (RLs) for non-detect analytes to health-based screening values. This comparison is presented in the subsections below.

Soil

The RLs for non-detected analytes were compared to the May 2012 residential soil RSLs (cancer risk = 1E-06; non-cancer HQ = 0.1). This comparison is presented in Table 2 of Appendix G-1-A. The RLs for all non-detected analytes were below the human health screening values. Based on this information, the analytical sensitivity for these analytes is not expected to contribute to the uncertainty.

Sediment

The RLs for non-detected analytes in the sediment samples were compared to the May 2012 residential soil RSLs (cancer risk = 1E-06; non-cancer HQ = 0.1). This comparison is presented in Table 3 of Appendix G-1-A.

For nitroglycerin, the high end of the RL range exceeded the health-based screening value. These samples were collected during the SI event. The more recent RI sediment samples had RLs below the screening value. These analytes were not detected in any of the samples collected at Nike Pond. This absence of detections indicates that their presence at the site is unlikely. For this reason, the SI RLs for nitroglycerin are not expected to contribute to the uncertainty. This conclusion is supported by the observation that potential exposure to sediment would be substantially less than the assumptions used in developing the residential soil RSLs.

Surface Water

The RLs for non-detected analytes in surface water samples were compared to the May 2012 tap water RSLs (cancer risk = 1E-06; non-cancer HQ = 0.1) (Table 4 of Appendix G-1-A). The maximum RLs for 1,3-dinitrobenzene, 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2-nitrotoluene, 3-nitrotoluene, and nitrobenzene were greater than the health-based screening values. These RLs were associated with the SI sample. The RLs for the three RI samples were less than the screening values. In addition, the tap water RSLs are very conservative screening values for the limited exposure that any receptor would have to the Nike Pond surface water. For these reasons, the SI RLs did not contribute to the uncertainty.

All RLs for nitroglycerin were greater than the tap water screening value. The RL for the SI sample was very elevated. For the RI samples, the nitroglycerin RL was approximately 3 times the screening value. Because the screening value corresponds to an HQ of 0.1, the RLs correspond to a HQ of approximately 0.3. If nitroglycerin were present in Nike Pond at concentrations less than the RL, then this chemical would not pose a threat to human health. Accordingly, the nitroglycerin RLs did not contribute to the HHRA uncertainty.

Groundwater

The range of RLs associated with the groundwater data are compared to the Federal MCLs and May 2012 tap water RSLs (cancer risk = 1E-06; non-cancer HQ = 0.1) in Table 5 of Appendix G-1-A. The RLs for antimony and thallium were greater than the health-based screening values but less than the MCLs. The antimony RL corresponds to a HQ of 0.2, indicating that this analytical sensitivity would not contribute substantially to the uncertainty. The thallium RL corresponds to an HQ of approximately 10. There is considerable uncertainty in the thallium RSL due to the uncertainty factor applied in derivation of the RfD, and the poor quality data set from which the RfD was derived (see below for additional details on the thallium RfD). The analytical sensitivity associated with the thallium RL could result in underestimation of potential risks associated with the potable water scenario.

The RLs for nitroglycerin were approximately three times the screening value, which corresponds to a HQ of 0.1. Thus, the RLs correspond to an approximate HQ of 0.3. If nitroglycerin were present in the groundwater at concentrations less than the RL, this chemical would not pose a threat to human health. For this reason, the nitroglycerin RL did not contribute substantially to the uncertainty.

6.2.4.2 Exposure Assessment

When evaluating exposure, probable scenarios are developed to estimate conditions and duration of human contact with COPCs. Scenarios are based on observations or assumptions about the current or potential activities of human populations which could result in direct exposure. To prevent underestimations of risk, scenarios incorporate exposure levels, frequencies, and durations at or near the top end of the range of probable values. This approach is sometimes termed a RME, one that may be at the high end of a range of exposures but still probable.

Default values, such as ingestion rates, were used in the exposure calculations to quantify intakes. Although these values are based on EPA-validated data, there is uncertainty in the applicability of such values to any particular exposed population or individual. To address this uncertainty, default values are typically selected to err on the side of conservatism.

Exposure point concentrations of COPCs are developed from the analytical results. It was assumed the contaminant levels used in the exposure calculations remained constant throughout the exposure period with no reduction due to chemical attenuation, depletion or degradation. This assumption is conservative and most likely results in overestimation of exposure. The associated uncertainty is that actual risk is less than estimated. In addition, for analytes detected in only a few samples, the maximum detected concentration was used as the exposure point concentration. The conservatism associated with this approach is illustrated by the groundwater exposure route. Because arsenic was detected in only four samples, the maximum concentration was used as the exposure point concentration. If the median detection is used as the exposure point concentration, the same exposure assumptions (ingestion rate, etc) result in a HI of 1 for the child resident, 0.6 for the adult resident, and cancer risk of 1E-04 for the age-adjusted resident. In this situation, the groundwater does not pose a non-cancer threat, and the cancer risks are at the upper end of the risk range.

Only 3 soil samples were collected at B003, which spans an estimated area of 2.2 acres. The samples were collected during the 2007 SI. The samples were biased. Use of only 3 soil samples to define conditions across 2.2 acres contributes substantially to the uncertainty. Depending on the actual extent of metals contamination, this approach could underestimate potential risks or, if the maximum detections represent a small, isolated area of contamination, could overestimate potential risks. The B003 soil data set is not of a sufficient quantity or quality to make reliable decisions concerning this area.

In addition, the small sample sizes for the majority of the MRSs (for example, one sample at MRS-3) contributes to the uncertainty associated with the risk assessment. This uncertainty is mitigated by the lack of MEC and MD found at these sites. With limited presence of MEC/MD, there is limited potential for a release to have occurred.

The uncertainty associated with the exposure assessment is appreciable. However, the uncertainty is generally from conservative overestimation of exposure variables. This approach is protective of potentially exposed populations. All of these factors contribute to a substantial but not unusually high level of uncertainty in the estimates of risk for all exposure pathways. The uncertainty is generally that risk has been overestimated, not underestimated.

6.2.4.3 Toxicity Assessment

All toxicity values were obtained from peer-reviewed sources in accordance with USEPA guidance. For some chemical substances, there is little or no toxicity information available and, for many chemicals, the available data are typically from animal studies. The relative strength of the available toxicological information generates some uncertainty in the evaluation of possible adverse health effects and the exposure level at which they may occur. To account for this uncertainty, the toxicity values developed from epidemiological studies are calculated in a conservative manner. While new epidemiological studies may indicate that existing toxicity values are not sufficiently protective, it is expected that the general approach to toxicity assessment would tend to err on the side of overestimating potential risks.

Numerical toxicity values for dermal exposure have not been developed by EPA. To quantify risk from dermal exposure, route to route extrapolation of the oral toxicity value to a dermal toxicity value was used. Because of potential differences in patterns of distribution, metabolism, and excretion between oral and dermal routes of exposure, use of oral toxicity values for dermal exposure may over- or underestimate risk, depending on the chemical.

A properly peer-reviewed RfD for thallium is not available. The RfD used in development of the USEPA RSL tables was derived from poor quality studies to which an uncertainty factor of 3,000 had been applied. The IRIS summary concluded that there was insufficient information to support development of a thallium RfD that could be used for risk assessment. Accordingly, the potential risks due to thallium exposure were not quantified for this risk assessment. However, because most of the thallium detections were consistent with Fort Hancock background results, the lack of RfD for this metal did not contribute substantially to the uncertainty at the majority of the sites. For B003, where the maximum detection suggested thallium contamination, the lack of RfD could underestimate potential risks.

6.2.5 Human Health Risk Assessment Summary and Conclusions

The baseline HHRA evaluated the current and potential future exposure of receptors to site media. The assessment considered the contributions from background constituents in addition to the potential effects associated with the site contaminants. This evaluation demonstrated that soil at MRS-1, MRS-3, MRS-5, MRS-6, and MRS-7 does not pose a threat to human health. The sediment and surface water at Nike Pond also do not pose a threat to human health. At the B003 Area, arsenic and lead in soil could pose a threat to human health. However, these conclusions are based largely on a single soil sample (out of 3 samples collected from the B003 Area as part of the SI in 2006) that contained the maximum detections of these metals. The low number of samples collected at the B003 Area (three SI soil samples) makes the risk conclusions for the B003 Area extremely conservative.

No samples were collected in MRS-2, MRS-4, and MRS-8, because no visible areas of breached MEC, evidence of energetics, or significant MD were encountered (per the approved Work Plan approach and sampling DQOs). Therefore, risk characterization (Section 6.2.3) was not performed for these MRSs.

The groundwater was treated as a single exposure unit across all the MRSs. There were two groundwater COPCs: arsenic and manganese. The manganese did not pose a threat to human health. For arsenic, the RME potable water scenario resulted in a cancer risk of 3E-04 and target organ HIs greater than 1 for the future resident. The following reasons support a risk management decision of no further action with respect to arsenic in the groundwater:

- Only the maximum concentration, 12.5 μg/L, was greater than the MCL of 10 μg/L. The median detection, 4.8 μg/L, was less than the MCL.
- The maximum detection was obtained from a well in an area characterized by background conditions with respect to arsenic in soil. Thus, there is no evidence of an arsenic release that may have affected the groundwater in this area.
- The detections were consistent with the range of typical arsenic concentrations in groundwater.
- The shallow groundwater is not currently used for any purpose. Future use of the shallow groundwater as a potable water supply is unlikely. Arsenic was not detected in the sample collected from the water supply well screened in the deep aquifer, approximately 800 feet below the shallow groundwater.

Finally, evaluation of the IS soil data indicated limited contamination in the vicinity of the BIP locations, but the potential contaminants did not pose a threat to human health based on comparison to the residential soil RSLs.

6.3 Ecological Evaluation

The SLERA is a conservative screening tool to assess whether site conditions indicate sufficient potential ecological threat to warrant further investigation or action, or whether the contamination poses no to minimal threat, thereby justifying a decision for no further action. Because of the conservatism associated with the Step 2 initial screening, the approach also included further data analysis with less conservative assumptions.

6.3.1 Step 1 – Problem Formulation

The initial step in the SLERA process was to formulate the problem. This step developed the CSM for the SLERA and defined the assessment and measurement endpoints. Fort Hancock provides habitat for several threatened species, endangered species, and species of concern. A list of these species is provided in Table 6-1.

Table 6-1. Threatened and Endangered Bird Species
Fort Hancock, NJ

Common Name	Scientific Name	Federal Status	State Status	Habitat	Potentially Occurs in MRSs?
American Bittern	*Botaurus lentiginosos*	-	E (BR)	Freshwater marsh	Yes
Bald Eagle	*Haliaeetus leucocephalus*	LT	E (BR) / T (NB)	Coastal estuary, coastal beach, large water bodies	Yes
Barred Owl	*Strix varia*	-	T	Woodland, Swamp	Yes
Black Rail	*Laterallus jamaicensis*	-	T	Saltwater marsh	Yes
Black Skimmer	*Rynchops niger*	-	E (BR) / T (NB)	Coastal beach	Yes
Black-crowned Night Heron	*Nycticorax nycticorax*	-	T (BR)	Freshwater marsh	Yes
Bobolink	*Dolichonyx oryzivorus*	-	T (BR)	Grassland	Yes
Cooper's Hawk	*Accipiter cooperii*	-	T	Woodland	Yes
Grasshopper Sparrow	*Ammodramus savannarum*	-	T (BR)	Grassland	Yes
Henslow's Sparrow	*Ammodramus henslowii*	-	E	Grassland	Yes
Least Tern	*Sterna antillarum*	-	E	Coastal beach	Yes
Loggerhead Shrike	*Lanius ludovicianus*	-	E	Grassland, orchard	Yes (rare)
Long-eared Owl	*Asio otus*	-	T	Woodland	Yes
Northern Goshawk	*Accipiter gentilis*	-	E (BR)	Woodland	Yes
Northern Harrier	*Circus cyaneus*	-	E (BR)	Grassland, dune	Yes
Osprey	*Pandion haliaetus*	-	T (BR)	Coastal estuary, coastal beach	Yes
Peregrine Falcon	*Falco peregrinus*	LE	E	Coastal areas, rivers,	Yes

Table 6-1. Threatened and Endangered Bird Species Fort Hancock, NJ					
Common Name	**Scientific Name**	**Federal Status**	**State Status**	**Habitat**	**Potentially Occurs in MRSs?**
				urban areas	
Pied-billed Grebe	*Podilymbus podiceps*	-	E	Freshwater marsh, saltwater marsh	Yes
Piping Plover	*Charadrius melodus*	T	E	Coastal beach, dune	Yes
Red Knot	*Calidris canutus*	C	T (BR)	Coastal beach	Yes
Red-headed Woodpecker	*Melanerpes erythrocephalus*	-	T	Woodland, savannah	Yes
Red-shouldered Hawk	*Buteo lineatus*	-	E (BR) / T (NB)	Woodland, open field	Yes
Roseate Tern	*Sterna dougallii*	E	E	Coastal beach	Yes
Savannah Sparrow	*Passerculus sandwichensis*	-	T (BR)	Grassland, saltwater marsh	Yes
Sedge Wren	*Cistothorus platensis*	-	E	Freshwater marsh, wet sedge or grass meadow	Yes (rare)
Short-eared Owl	*Asio flammeus*	-	E (BR)	Saltwater marsh, dune	Yes
Upland Sandpiper	*Batramia longicauda*	-	E	Grassland	Yes
Vesper Sparrow	*Pooecetes gramineus*	-	E (BR) / T (NB)	Grassland	Yes
Yellow-crowned Night Heron	*Nyctanassa violaceus*	-	T	Freshwater marsh	Yes

Notes:
Table excerpted from Work Plan (ERT, 2010)
Federal Status Codes: E = Endangered T = Threatened LE = Formerly Listed as Endangered
Federal Status Codes (continued): LT = Formerly Listed as Threatened C = Candidate for Federal Listing
State Status Codes: E = Endangered T = Threatened
BR = Breeding Population Only NB = Non-breeding Population Only

In addition, Fort Hancock encompasses rare habitat, such as the Maritime Holly Forest. A detailed description of the different ecosystems and species present at Fort Hancock is presented in Section 2.1.8. Based on the species and habitats present, the potential for ecological risks at Fort Hancock is of particular concern.

Residences and non-resident facilities are not present in the MRSs. While the MRSs may encompass roads and parking lots, it is expected that each of the MRSs represents terrestrial habitat. The only aquatic habitat within the investigation areas is the Nike Pond. The assessment and measurement endpoints for the terrestrial habitat and aquatic habitat are presented in Table 1 of Appendix G-2. Endpoints include plant and invertebrate communities in addition to wildlife communities that could be exposed to site contaminants through consumption of dietary items in which the contaminants have accumulated. For each potentially-affected feeding guild, representative species were selected to provide a conservative evaluation.

The three potentially-affected terrestrial avian communities (granivores, insectivores, and carnivores) were represented by the mourning dove (granivore), American woodcock (insectivore), and red-tailed hawk (carnivore). For terrestrial mammals, the representative species were the meadow vole (herbivore), short-tailed shrew (insectivore), and red fox (carnivore). Animals that could eat fish and other prey which live in Nike Pond were represented by the great blue heron and mink.

A preliminary CSM was developed to depict the potential exposure routes by which ecological receptors could contact site contaminants. The preliminary CSM is shown graphically on Figure G-2-1 (presented at the end of Appendix G-2), and the potential exposure routes are listed below.

- Soil:
    - Direct contact; and
    - Bioaccumulation into plants, soil invertebrates, and small mammals, and consumption of these food items.
- Sediment:
    - Incidental ingestion; and
    - Bioaccumulation into sediment invertebrate tissue and consumption of the invertebrates.
- Surface water:
    - Ingestion; and
    - Bioaccumulation into fish and consumption of fish.

6.3.2 Step 2 – Approach for the Initial Screening

The screening level step is a very conservative evaluation in which the maximum concentration in a particular medium was compared to benchmark values for a target community (e.g., terrestrial plants) or was used to estimate the chemical consumption rate for comparison to no observed adverse effect levels (NOAELs) for wildlife receptors (e.g., mammalian insectivore). Because of their status as essential nutrients, calcium, magnesium, potassium, and sodium were not to be considered in the SLERA. The approach used for the initial screening is discussed below.

6.3.2.1 Terrestrial Plant and Soil Invertebrate Communities

USEPA's Ecological Soil Screening Levels (Eco-SSLs) (USEPA, 2003b, with updates) is the preferred source of benchmark values protective of terrestrial plants and soil invertebrates. However, only a limited number of Eco-SSLs are available. For chemicals without Eco-SSLs, benchmark values were obtained from the following sources in the order listed below:

- NJDEP Ecological Screening Criteria Table;
- Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision (Efroymson, et al., 1997a);

- Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Processes: 1997 Revision (Efroymson, et al., 1997b); and
- Other sources, including USEPA Region 5 Ecological Screening Levels, and Attachment 1-1 of the USEPA Guidance for Developing Ecological Soil Screening Levels (USEPA, 2003b).

The maximum concentration of each analyte detected in the surface soil was compared to its benchmark value. Analytes with detected concentrations greater than their benchmark values were retained for further analysis.

6.3.2.2 Aquatic Community

The surface water results for Nike Pond were screened against freshwater aquatic benchmarks. These benchmarks were obtained from the following sources:

- NJDEP Ecological Screening Criteria Table (chronic values);
- USEPA Region 5 Ecological Screening Levels;
- Toxicological Benchmarks for Screening of Potential Contaminants of Concern for Effects on Aquatic Biota on Oak Ridge Reservation: 1996 Revision (Suter, G.W. II, and C.L. Tsao. 1996);
- USEPA Region 3 Freshwater Screening Benchmarks; and
- Other sources as required (USEPA Region 6, etc.).

The maximum concentration of each analyte detected in the surface water samples was compared to its benchmark value. Analytes with detected concentrations greater than their benchmark values were retained for further analysis.

6.3.2.3 Benthic Invertebrate Community

The Nike Pond sediment data were screened against benchmarks protective of the freshwater benthic invertebrate community. These benchmarks were obtained from the following sources:

- NJDEP Ecological Screening Criteria Table (low effects levels);
- USEPA Region 5 Ecological Screening Levels;
- USEPA Region 3 Freshwater Sediment Benchmarks; and
- Other sources as required (USEPA Region 6, etc.).

The maximum concentration of each analyte detected in the sediment samples were compared to its benchmark value. Analytes with detected concentrations greater than their benchmark values were retained for further analysis.

6.3.2.4 Wildlife Receptors

The Eco-SSLs include concentrations protective of mammals and birds. Only a few chemicals are characterized by Eco-SSLs, and the Eco-SSLs apply only to soil. For those chemicals with mammalian and/or avian Eco-SSLs, these benchmark values were used for the initial screening for wildlife receptors. The maximum concentration of each detected analyte was compared to its

Eco-SSL. Chemicals with detected concentrations greater than the Eco-SSLs were retained for the central tendency food web analysis.

For chemicals without Eco-SSLs, including chemicals detected in sediment and surface water samples, the potential food web effects were assessed by estimating the chemical intake for each upper trophic level receptor and comparing this intake to the NOAEL. Chemical intake included direct ingestion of the contaminated medium (e.g., incidental consumption of soil; drinking of surface water; etc.) and the ingestion of chemicals accumulated in the tissue of the wildlife receptor's diet (plants, invertebrates, mammals, and/or fish). Although wildlife receptors may be exposed to chemicals via dermal contact and inhalation, these exposure routes typically are negligible when compared to ingestion (USEPA, 2003b, as updated in 2005). Therefore, intake via these exposure routes was not quantified. Table 2 of Appendix G-2 identifies the exposure assumptions (food ingestion rate, dietary components, etc.) that were used to quantify chemical intake for each wildlife receptor. The preferred source of NOAELs is the Eco-SSL documents. The alternate source of NOAELs was Toxicological Benchmarks for Wildlife: 1996 Revision (Sample, et al., 1996). Chemicals that resulted in a NOAEL-based quotient greater than 1 were retained for the central tendency food web analysis. The dietary exposure route was evaluated only for the important bioaccumulative chemicals identified in Table 4-2 of Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment: Status and Needs (USEPA, 2000b). Explosives are not identified as important bioaccumulative chemicals in this document. The potential effects of explosives were evaluated on the basis of the available benchmark values.

For the initial screening, chemical intake was estimated from the maximum detected concentration in each exposure medium with the following equation:

$$E_j = [Cs_j \times P_s \times FIR][AUF] + [AUF]\left[\sum_{i=1}^{N} B_{ij} \times P_i \times FIR\right] + [\text{Cwj x WIR x AUF}]$$

Where:

E_j	=	total exposure (mg/kg/d)
Cs_j	=	concentration of chemical (j) in soil or sediment (mg/kg)
P_s	=	soil or sediment ingestion rate as proportion of diet
FIR	=	species-specific food ingestion rate (kg food/kg body weight/d)
B_{ij}	=	concentration of chemical (j) in biota type (i) (mg/kg)
P_i	=	proportion of biota type (i) in diet
Cwj	=	concentration of chemical (j) in surface water (mg/kg)
WIR	=	water ingestion rate (kg water/kg body weight/d)
AUF	=	area use factor (unitless) [used value of 1 for initial screening]

As indicated by the above equation, in order to calculate chemical intake, it is necessary to estimate chemical bioaccumulation. The equations or models that were used to estimate tissue concentrations from soil, sediment, or surface water concentrations are described below.

Attachment 4-1 of USEPA's Guidance for Developing Ecological Soil Screening Levels (USEPA, 2003b, as updated in 2007) provides soil-to-plant, soil-to-earthworm, and soil-to-mammal equations or bioaccumulation factors (BAFs) for a number of inorganic and organic chemicals. This USEPA document was the primary source for uptake models. If an uptake model for a particular chemical was not available in the USEPA document, then the following documents were consulted:

- Baes, C.F. III; R.D. Sharp; A.L. Sjoreen; and R.W. Shor, 1984. A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture. Oak Ridge National Laboratory, ORNL-5786.
- Bechtel-Jacobs, 1998a. Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants. Prepared for U.S. Department of Energy. BJC/OR-133, September.
- Sample, B.E.; J.J. Beauchamp; R.A. Efroymson; and G.W. Suter II, 1998. Development and Validation of Bioaccumulation Models for Small Mammals. ES/ER/TM-219.
- Sample, B.E.; G. W. Suter II; J.J. Beauchamp; and R.A. Efroymson, 1999. Literature-Derived Bioaccumulation Models for Earthworms: Development and Validation. Env. Toxicol. Chem., Vol. 18, No. 9, pp. 2110-2120.

If a suitable BAF could not be found in the documents listed above, or in a scientific literature resource of suitable quality, a default value of 1 was used. The general form of the BAF equation is presented below:

$$B_{ij} = Cs_j \text{ x } BAF_{ij}$$

Tissue concentrations in benthic invertebrates were estimated in accordance with the models provided in Bechtel-Jacobs (1998b). If a chemical could not be modeled with these models, or if one could not be obtained from a scientific literature source of suitable quality, a default biota-sediment accumulation factor (BSAF) of 1 was assumed. Although the general form of the BSAF equation is for the benthic invertebrate tissue concentration to be equal to the sediment concentration multiplied by the BSAF (i.e., $C_{benthic}$ = BSAF x Cs), the models in Bechtel-Jacobs (1998b) are in the form of log-linear equations.

Tissue concentrations in fish were estimated by multiplying the measured surface water concentration for each chemical by the bioconcentration factor (BCF) (i.e., C_{fish} = BCF x Cw). BCFs were obtained from Appendix H of Technical Support Document for Exposure Assessment and Stochastic Analysis (California Environmental Protection Agency (CalEPA), 2000) or from the octanol-water partition coefficient equation identified in Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (USEPA, 2003c). If a BCF could not be obtained from a scientific literature source of suitable quality, a default value of 1 was assumed.

6.3.3 Initial Screening – Soil Data

The maximum concentration of each analyte detected in the soil samples was compared to screening values, which provide conservative benchmarks for the protection of ecological receptors. The results of this screening are provided in Tables 3 through 7 of Appendix G-2, and are summarized below by MRS. If an analyte had more than one benchmark value available to address multiple communities, the lowest benchmark was used for the initial screening.

No samples were collected in MRS-2, MRS-4, and MRS-8, based on the approved Work Plan approach and sampling DQO. Therefore, ecological risk characterization was not performed for these MRSs. Revised CSMs based on the findings of the RI are presented at the end of Appendix G-2. The revised CSMs for MRSs 1, 3, 6, and 7 are presented as Figure G-2-2. The revised CSM for the Grid B003 Area is presented as Figure G-2-3, and the revised CSM for MRS-5 is presented as Figure G-2-4.

6.3.3.1 MRS-1

The initial screening of the MRS-1 soil data is presented in Table 3 of Appendix G-2. As shown in this table, benchmark values were not available for aluminum, iron, strontium, and zirconium. The maximum aluminum detection, 1,230 mg/kg, was less than the range of concentrations, 1,460 – 2,030 mg/kg, reported for the Fort Hancock background samples. In addition, the maximum iron concentration, 13,000 mg/kg, was within the range of concentrations (8,120 – 13,200 mg/kg). These comparisons indicate that any potential effects associated with aluminum and iron would reflect background conditions.

Excluding the maximum detection of 19.6 mg/kg, the strontium results, 1.4 – 9.1 mg/kg were similar to the range of concentrations, 1.6 – 8.8 mg/kg, reported for the Fort Hancock background samples. Because only three background soil samples were collected at Fort Hancock, this background data set may not encompass the full natural range of strontium concentrations at the site. According to the Agency for Toxic Substance and Disease Registry (ATSDR), the typical range of strontium concentrations in soil is 0.2 – 20 mg/kg (ATSDR, 2004). The maximum detected concentration, 19.6 mg/kg, is within this range. The soil data do not indicate the presence of strontium contamination. Accordingly, this metal was not retained as a chemical of potential ecological concern (COPEC).

The maximum and average zirconium detections at MRS-1, 20.9 mg/kg and 10.6 mg/kg, respectively, were only slightly greater than the maximum (18 mg/kg) and average (9.2 mg/kg) concentrations reported for the Fort Hancock background samples. This comparison does not indicate the presence of zirconium contamination. Accordingly, it is unlikely that zirconium at MRS-1 poses a threat to the environment.

Benchmark values were available for the remaining analytes detected in the MRS-1 samples. Maximum concentrations of antimony, chromium, copper, lead, mercury, vanadium, and zinc were greater than the ecological benchmark values. The maximum chromium detection of 18.2 mg/kg was slightly less than the 90th percentile (18.7 mg/kg) for the NJ background data. The maximum copper, lead, vanadium, zinc, and mercury detections were less than the average NJ background concentrations. Based on comparison to the NJ background values, these metals were identified as background constituents. The maximum antimony detection of 1.8 mg/kg was greater than the maximum NJ background values, but less than the maximum concentration reported for the Fort Hancock background samples, indicating that the antimony also represents background conditions. Because any potential effects associated with these metals would be consistent with background risks, no metals were retained as COPECs.

6.3.3.2 MRS-3

The initial screening for MRS-3 is presented in Table 4 of Appendix G-2. As described for MRS-1, benchmark values were not available for aluminum, iron, strontium, and zirconium. The detections for these four metals were less than or within the range of concentrations reported for the Fort Hancock background samples. Because these metals represent background conditions, any potential ecological risks would also reflect background conditions. For this reason, these four metals were not retained as COPECs.

Detections of antimony, chromium, lead, mercury, and vanadium were greater than the benchmark values. The chromium concentration, 12.5 mg/kg, was approximately equal to the average NJ background concentration of 12.1 mg/kg. The lead, mercury, and vanadium concentrations were less than the average NJ background values. Chromium, lead, mercury, and vanadium were identified as background constituents. Because these metals reflect background conditions, they were not retained as COPECs.

The antimony detection, 1.3 mg/kg, was approximately twice the maximum NJ background concentration of 0.69 mg/kg, but less than the range of values reported for the Fort Hancock background samples (≤ 2.6 mg/kg). Antimony was identified as a background constituent, and thus was not retained as a COPEC.

6.3.3.3 MRS-5

The MRS-5 soil results are screened in Table 5 of Appendix G-2. As described above for MRS-1 and MRS-3, benchmark values were not available for aluminum, iron, strontium, and zirconium. The maximum aluminum, iron, and strontium detections were less than or within the range of background values for Fort Hancock. These three metals were identified as background constituents, and thus were not retained for further evaluation.

The maximum zirconium concentration, 69.2 mg/kg, was greater than the maximum Fort Hancock background concentration of 18 mg/kg. Due to the limited number of background samples, the range of background concentrations may not encompass the full range of background conditions at the site. A study by Shacklette and Boerngen (1984) measured zirconium concentrations in soil across the United States. For the eastern half of the country, the mean zirconium concentration was 220 mg/kg. The maximum concentration at MRS-5 was less than this mean value, suggesting that the zirconium reflects background conditions. In addition, zirconium is purported to be of low toxicity. For these reasons, zirconium was not retained for further evaluation.

The maximum detections of antimony, chromium, lead, mercury, and vanadium were greater than the benchmark values. The lead, mercury, and vanadium concentrations were less than the average NJ background values. The maximum antimony detection, 0.53 mg/kg, was less than the maximum NJ background value of 0.69 mg/kg. In addition, the maximum chromium concentration, 16.3 mg/kg, was less than the 90^{th} percentile (18.7 mg/kg) of the NJ background data set. These five metals were identified as background constituents. Because any potential ecological threats would reflect background conditions, none of the metals was retained for further evaluation.

6.3.3.4 MRS-6

The initial screening for the MRS-6 data is presented in Table 6 of Appendix G-2. As stated previously, screening values are not available for aluminum, iron, strontium, and zirconium. The maximum detections of these four metals at MRS-6 were less than or within the range of Fort Hancock background results, indicating that these metals represent background conditions.

Because any potential ecological risks associated with these four metals would reflect natural site conditions, these metals were not retained for further evaluation.

The maximum detections of antimony, chromium, mercury, and vanadium were greater than the benchmark values. The maximum detections of chromium, mercury, and vanadium were less than the average NJ background values. In addition, the maximum antimony detection, 0.54 mg/kg, was less than the maximum NJ background concentration of 0.69 mg/kg. Because the four metals represent background conditions, they were not retained for further evaluation.

6.3.3.5 MRS-7

The MRS-7 soil results are compared to the benchmark values in Table 7 of Appendix G-2. Screening values were not available for aluminum, iron, and zirconium. The maximum concentrations for these three metals were less than or within the range of Fort Hancock background values. Aluminum, iron, and zirconium were identified as background constituents. Accordingly, they were not retained for further evaluation.

The maximum detections of antimony, chromium, lead, mercury and vanadium were greater than the ecological benchmarks. The maximum lead and mercury detections were less than the average NJ background concentrations. The maximum chromium concentration, 24.8 mg/kg, was approximately equal to the maximum NJ background result of 24.6 mg/kg. The maximum vanadium detection, 30.1 mg/kg, was less than the 90^{th} percentile of the NJ background data set (39.9 mg/kg). These comparisons indicate that chromium, lead, mercury, and vanadium are background constituents at MRS-7. Accordingly, these metals were not retained for further evaluation.

The maximum antimony concentration, 1.6 mg/kg, was approximately twice the maximum concentration reported for the NJ background study but less than the range of values reported for the Fort Hancock background samples (≤ 2.6 mg/kg). Antimony was identified as a background constituent, and thus was not retained as a COPEC.

6.3.3.6 B003 Area

The B003 Area soil data are compared to the benchmark values in Table 8 of Appendix G-2. Screening values were not available for aluminum, iron, strontium, and zirconium. The aluminum concentrations, which ranged from 1,000 – 1,790 mg/kg, were consistent with the concentrations reported for the Fort Hancock background samples (1,460 – 2,030 mg/kg). The maximum strontium concentration of 7.8 mg/kg was less than the maximum Fort Hancock background concentration of 8.8 mg/kg. The maximum zirconium concentration, 22.8 mg/kg, was similar to the maximum Fort Hancock background concentration of 18 mg/kg. The other two zirconium detections, 8.6 mg/kg and 7.1 mg/kg, were on the low end of the range of Fort Hancock background values. Aluminum, strontium, and zirconium were identified as background constituents. As discussed in Section 6.2.3.6, iron was identified as a contaminant.

The maximum detections of antimony, arsenic, chromium, copper, lead, mercury, molybdenum, selenium, silver, thallium, vanadium, and zinc were greater than the ecological benchmark values. The maximum mercury and vanadium concentrations were less than the average NJ background values. The maximum chromium concentration, 17.9 mg/kg, was less than the 90^{th} percentile of the NJ background data set. The maximum zinc concentration, 371 mg/kg, was less than the maximum NJ background value of 789 mg/kg. The remaining metals were identified as potential contaminants, and were retained for further evaluation with respect to all terrestrial endpoints.

6.3.3.7 Summary

In summary, antimony, arsenic, copper, lead, molybdenum, selenium, silver, and thallium in the B003 soil were retained for further evaluation. For MRS-1, MRS-3, MRS-5, MRS-6, and MRS-7, the metals which exceeded benchmark values or which did not have screening values were identified as background constituents. At these sites, there is no evidence of soil contamination that could pose a threat to ecological receptors.

It should be noted that the initial food web analysis was not performed either because the benchmark values included Eco-SSLs protective of wildlife receptors, or the bioaccumulative metal which lacks Eco-SSLs (mercury) was identified as a background constituent.

6.3.4 Initial Benchmark Screening – Sediment at Nike Pond

To assess potential effects to the benthic invertebrate community, the sediment results were compared to sediment benchmarks. As discussed in Section 6.1.1, the sediment data set included the pooled RI and SI samples. This data screening is presented in Table 9 of Appendix G-2.

The maximum detections of 2,6-dinitrotoluene, antimony, arsenic, chromium, copper, lead, mercury, and selenium were greater than the benchmark values. All of these detections were reported for the 2007 SI sediment sample FHK-LD-SD-06-02. In the 2011 RI samples, 2,6-dinitrotoluene and antimony were not detected, and the maximum concentrations of arsenic, chromium, copper, lead, and mercury were less than the benchmark values (the RI samples were not analyzed for selenium). Based solely on the RI data, no results are greater than the benchmark values.

Background sediment data are not available. However, because sediment represents eroded soil, a qualitative comparison of the analytical results to soil background levels can indicate whether a metal reflects likely background conditions. For example, the maximum arsenic concentration, 7.7 mg/kg, was consistent with background values for soil, suggesting that this metal is naturally occurring. The maximum mercury concentration of 0.34 mg/kg was approximately equal to the median NJ background concentration (0.31 mg/kg) and less than the average NJ background concentration (0.5 mg/kg). In addition, mercury was detected in only three other sediment samples, and the concentrations ranged from 0.02 J mg/kg to 0.03 J mg/kg. These data do not indicate the presence of mercury contamination. Similarly, the maximum copper concentration in sediment was 41.2 mg/kg, and all other copper detections were less than 10 mg/kg. These concentrations are less than the average NJ background soil concentration of 42.2 mg/kg. Based on these comparisons, arsenic, copper, and mercury in sediment were identified as background constituents. Because any potential ecological risks associated with these metals would reflect background conditions, arsenic, copper, and mercury were not retained for further evaluation.

2,6-Dinitrotoluene, antimony, chromium, lead, and selenium were retained for further evaluation with respect to potential impacts for the benthic invertebrate community.

Screening values were not available for barium, beryllium, molybdenum, strontium, thallium, titanium, vanadium, and zirconium. As described above for the soil screening, the soil data provide no evidence that strontium or zirconium were released during historical site use. For this reason, it is unlikely that either metal would be a contaminant in the sediment. The maximum beryllium concentration was less than the average NJ background concentration for soil, suggesting that the beryllium represents natural conditions from eroded soil. Thallium was detected in only two sediment samples, and the concentrations, both 0.5 J mg/kg, were similar to the range of soil concentrations found across NJ (≤ 0.46 mg/kg). Because the data provide no evidence of strontium, zirconium, beryllium, or thallium contamination, these four metals were not retained for further evaluation.

The maximum barium concentration, 10.2 mg/kg, and maximum molybdenum concentration, 1.2 mg/kg, were low. Both metals exhibit relatively low toxicity. Based on their low concentrations, these metals were not retained for further evaluation. Similarly, titanium is also expected to exhibit low toxicity.

Excluding the maximum detection of 51.7 mg/kg, the vanadium concentrations ranged from 5.7 mg/kg to 15.4 mg/kg. This range of concentrations is consistent with the Fort Hancock background soil concentrations and is on the low end of the NJ background values. In addition, the maximum sediment detection was only slightly greater than the maximum NJ background soil concentration of 46.1 mg/kg. Given that the sediment reflects the eroded soil, these comparisons provide no evidence of vanadium contamination in Nike Pond. For this reason, vanadium was not retained for further evaluation.

6.3.5 Initial Benchmark Screening – Surface Water at Nike Pond

In the surface water samples, arsenic, chromium, copper, lead, manganese, thallium, titanium, vanadium, and zinc were positively detected. Antimony, barium, cadmium, and mercury were not detected. The aqueous data were screened against chronic benchmark values in Table 10 of Appendix G-2. The maximum aqueous concentrations of copper and lead were greater than their respective benchmark values. These analytes are discussed below.

The maximum aqueous copper result was greater than the benchmark value calculated using an assumed hardness of 50 mg/L. The copper concentration of 0.018 mg/L in sample FHRI-05-SW-02 DUP was four times the calculated benchmark value of 0.0045 mg/L. In the other surface water samples, the copper concentration ranged from 0.0016 mg/L to 0.0065 mg/L. Use of 50 mg/L is a conservative hardness value for calculating the benchmark value. The average copper concentration, 0.0079 mg/L, was less than twice this conservative benchmark value. In addition, there is no evidence of copper contamination in the Nike Pond sediment (Section 6.3.4). Based on these lines of evidence, copper was not retained as a COPEC.

The maximum lead concentration, 0.0066 mg/L, was 1.2 times the chronic benchmark value of 0.0054 mg/L. The average lead concentration, 0.0047 mg/L, was less than the chronic benchmark value. Lead does not pose a threat to the aquatic community.

A screening value was not available for titanium. The titanium detections ranged from 0.0024 mg/L to 0.007 J mg/L. These low concentrations indicate limited presence of this metal in the aqueous phase. In addition, titanium is expected to have low toxicity. For these reasons, titanium was not retained for further evaluation.

The above evaluation indicates that the Nike Pond surface water does not pose a threat to the aquatic community.

6.3.6 Initial Food Web Analysis – Nike Pond

Exposure of birds and mammals that eat fish and benthic invertebrates to the bioaccumulative metals detected in the Nike Pond samples was evaluated through food web modeling. The BSAFs and BCFs are listed in Table 11, and the food web calculations are provided in Table 12 of Appendix G-2. All NOAEL ecological quotients were less than or equal to 1, indicating that the bioaccumulative metals detected in the Nike Pond samples do not pose a threat to aquatic birds or mammals.

6.3.7 Central Tendency Evaluation

As described in the above sections, the following analytes were retained for further evaluation:

- Antimony, arsenic, copper, lead, molybdenum, selenium, silver, and thallium in the B003 Area soil; and
- 2,6-Dinitrotoluene, antimony, chromium, lead, and selenium in the Nike Pond sediment.

The soil COPECs were retained for further evaluation with respect to all terrestrial endpoints. The sediment COPECs were retained for further evaluation with respect to the benthic invertebrate community.

The initial screening in Step 2 was based on very conservative exposure assumptions. Because it is conservative, Step 2 will significantly overestimate the potential for chemicals retained in the screening process to pose an ecological threat. In the CTE, the exposure assumptions were modified to make the assessment a more realistic reflection of site conditions. The risk evaluation was modified in the following manner:

- For all assessment endpoints where exposure is based on media concentrations, the comparison of the maximum concentrations to the benchmark values was augmented by an analysis of the spatial extent to which the data set exceeds the benchmarks and the potential magnitude of impacts to the overall community.
- For wildlife, chemical intake was estimated with both the maximum detected concentration and the median detected value. Typically, a 95% UCL is used for this evaluation, but the number of samples collected at the B003 Area was too small to support a UCL calculation. Site use relative to home range size was incorporated into the assessment. Central tendency food ingestion rates were used instead of maximum food ingestion rates. The spatial distribution of the contaminants was considered, along with whether the chemical intake was equal to or greater than the lowest observed adverse effects level (LOAEL). LOAELs were obtained either by calculating the geometric mean of the LOAELs for reproduction, growth, and survival listed in the Eco-SSL documents (preferred source) or from Toxicological Benchmarks for Wildlife: 1996 Revision (Sample, et al., 1996).

6.3.7.1 Refined Comparison to Benchmarks for Plants and Terrestrial Invertebrates

The B003 Area antimony maximum concentration (26.4 mg/kg) was less than the soil invertebrate Eco-SSL of 78 mg/kg but greater than the plant benchmark of 5 mg/kg. The other two antimony detections were less than the plant benchmark. However, because only three samples were collected across an estimated area of approximately 2.2 acres, the actual extent of the antimony contamination within the B003 Area may not be known. For this reason, antimony was retained as a COPEC for the plant community.

The B003 Area arsenic maximum concentration (114 mg/kg) was greater than the plant Eco-SSL of 18 mg/kg and the soil invertebrate benchmark value of 60 mg/kg. The other two arsenic detections were less than the plant Eco-SSL and invertebrate benchmark. The maximum arsenic concentration was less than twice the soil invertebrate benchmark of 60 mg/kg, suggesting limited potential for the arsenic contamination to affect the invertebrate community. As discussed above for antimony, it is difficult to assess whether the arsenic contamination poses a threat to the plant community. For this reason, arsenic was retained as a COPEC for the plant community.

The B003 copper concentration was greater than the plant Eco-SSL (70 mg/kg) and soil invertebrates Eco-SSL (80 mg/kg) in two samples: FHK-NP-SS-06-03 (384 mg/kg) and FHK-NP-SS-06-02 (81.1 mg/kg). Depending on the lateral extent of the copper contamination and its bioavailability, the copper contamination may affect the plant and terrestrial communities. Copper was retained as a COPEC for both of these communities.

The lead concentration was greater than the plant Eco-SSL (120 mg/kg) in two samples: FHK-NP-SS-06-03 (2180 mg/kg) and FHK-NP-SS-06-01 (152 mg/kg). The detection at FHK-NP-SS-06-03 was 18 times the plant Eco-SSL. Depending on the lateral extent of this lead contamination and its bioavailability, it may affect the plant community. The maximum lead concentration at MRS-1, 2,180 mg/kg, also exceeded the invertebrate Eco-SSL (1,700 mg/kg). Based on the low ratio by which the benchmark value was exceeded, 1.3, it is unlikely that the lead contamination poses a threat to the soil invertebrate community. Lead was retained as a COPEC for the plant community.

The maximum molybdenum detection, 2.3 mg/kg, was only slightly greater than the benchmark value of 2 mg/kg. The other two molybdenum results were less than the benchmark value. Based on slight ratio by which the benchmark value was exceeded, molybdenum is unlikely to pose a threat to ecological receptors. This metal was not retained as a COPEC.

The maximum selenium concentration of 3.6 mg/kg was less than the invertebrate Eco-SSL of 4.1 mg/kg but greater than the plant Eco-SSL of 0.52 mg/kg. All three selenium detections in the B003 samples were greater than this Eco-SSL. Selenium is not mobile, and thus not bioavailable, under acidic conditions. Although none of the B003 soil samples was analyzed for pH, the MRS-7 pH result of 4.22 suggests that the soil at Fort Hancock is acidic. Under these conditions, it is unlikely that the selenium concentrations could affect the plant community. For this reason, selenium was not retained as a COPEC for the plant community.

The maximum silver concentration, 7.6 mg/kg, was less than the plant Eco-SSL (560 mg/kg). A benchmark value for soil invertebrates is not available. Beglinger & Ruffing (1997, as cited in CICAD 44 [WHO, 2002]) found no effect of 1,600 mg silver/kg dry weight of soil (applied as silver sulfide) on mortality, burrowing time, appearance, or weight of earthworms (*Lumbricus terrestris*) exposed for up to 14 days. This study suggests that the maximum concentration observed at B003 would not adversely affect terrestrial invertebrates. Silver was not retained as a COPEC for either plants or soil invertebrates.

Thallium was detected in one B003 Area soil sample at a concentration of 6.5 mg/kg. This result was greater than the plant benchmark of 1 mg/kg. A benchmark value was not available for invertebrates. A study performed by Heim, et al. (2002) estimated lowest observed effects concentrations (LOECs) of 1 mg/kg for hatching of *Arianta arbustorum* and 5 mg/kg for reproduction of *Eisenia fetida*. Because of the limited number of samples collected at B003, the lateral extent of the thallium contamination is not known. Based on this uncertainty and the comparison to the available toxicity information, thallium was retained as a COPEC for the plant and soil invertebrate communities.

In summary, antimony, arsenic, copper, lead, and thallium contamination at the B003 Area may pose a threat to the plant and/or soil invertebrate communities. Molybdenum, silver, and selenium are unlikely to pose a threat to these communities.

6.3.7.2 Refined Terrestrial Food Web Analysis

The BAFs used in the terrestrial food web calculations are provided in Tables 13 and 14 of Appendix G-2. The calculations for the refined food web analysis are presented in Table 15 (maximum detected concentration) and Table 16 (median detected concentration) of Appendix G-2.

At the B003 Area, the maximum arsenic and silver concentrations resulted in NOAEL ecological quotients less than 1. These metals do not pose a threat to wildlife receptors.

The maximum detections of antimony, copper, lead, and selenium resulted in NOAEL ecological quotients greater than 1 for the insectivorous mammal (all metals), insectivorous bird (copper and lead), and granivore (copper and lead). The median detections of these metals resulted in NOAEL ecological quotients greater than 1 for exposure of the granivore and insectivorous bird to lead and the insectivorous mammal to antimony. These results suggest that the lead and antimony contamination could pose a threat to wildlife receptors. Depending on the lateral extent of the copper and selenium contamination, these metals could also pose a threat.

In summary, antimony, copper, lead, and selenium were retained as COPECs for wildlife receptors at the B003 Area.

6.3.7.3 Refined Comparison to Sediment Benchmark Values

2,6-Dinitrotoluene, antimony, chromium, lead, and selenium in the Nike Pond sediment were retained for further evaluation. Each of these chemicals is discussed below.

2,6-Dinitrotoluene was detected in only 1 of 8 sediment samples. It was not detected in any of the RI samples. Based on its limited occurrence, it is unlikely that this explosive poses a threat to the benthic invertebrate community.

The maximum antimony detection was only 1.1 times the benchmark value. In addition, the metal was detected in only two sediment samples. Based on the low ratio by which the benchmark was exceeded and its limited occurrence, antimony does not pose a threat to the benthic invertebrate community.

The maximum chromium detection was 1.3 times the benchmark value. All other detections were less than the benchmark value. Based on the limited extent to which the benchmark value was exceeded, it is unlikely that chromium poses a threat.

Only the maximum lead detection, reported for one of the SI samples, was greater than the benchmark value. Furthermore, the lead detections were in the range of NJ background concentrations (≤ 617 mg/kg). Because sediment reflects eroded soil, the similarity between the sediment data and the NJ background data suggest that lead is not a contaminant in the Nike Pond sediment. Based on the single lead concentration greater than the benchmark value and limited potential for the lead to represent contamination, this metal was not retained as a COPEC for sediment.

The maximum selenium concentration, 2.5 mg/kg, was only 1.25 times the benchmark value. Based on the low ratio by which the benchmark value was exceeded, selenium does not pose a threat to benthic invertebrates.

In summary, the constituents in the Nike Pond sediment do not pose a threat to the benthic invertebrate community.

6.3.8 Uncertainty Analysis

As described in the uncertainty analysis for the HHRA, the selection of the analytical suite based on historical site use, the collection of field samples in accordance with the planning documents, and the validation of the analytical results in accordance with the QAPP minimize the potential uncertainty associated with the reliability of the analytical data and the identification of site contaminants.

The lack of screening values for several metals could result in underestimation of the potential ecological threats. However, the metals that lacked screening values were identified as background constituents. Because any potential risks associated with these metals would reflect natural site conditions, this uncertainty has limited effect on the SLERA's conclusions.

To assess the uncertainty associated with the analytical sensitivity, the RLs for analytes not detected in the soil, sediment, or surface water samples were compared to ecological benchmark values. This comparison is presented in Tables 2 through 5 of Appendix G-1-A and summarized below.

Soil

The RLs for 2,6-dinitrotoluene, ranging from 0.04 mg/kg to 0.063 mg/kg, were greater than the benchmark value of 0.0328 mg/kg. The maximum RL was approximately twice the benchmark value. Thus, if this explosive were present at concentrations less than the RL, it is unlikely that it would pose a threat to ecological receptors.

For the majority of the explosives, ecological benchmark values were not available. Most of the RLs for these explosives were low, less than or equal to 0.08 mg/kg. With this analytical sensitivity, it is unlikely that these explosives are present at levels that could pose an ecological threat. The RLs for nitroglycerin (0.25 – 4 mg/kg) and PETN (0.2 – 0.44 mg/kg) were relatively high. If these two explosives are actually present at the MRSs, the elevated RLs could have resulted in underestimation of ecological risks.

Sediment

The RLs for 1,3-dinitrobenzene, 2,4-dinitrotolouene, and RDX were greater than their sediment benchmark values. The maximum RLs were above the benchmark values by ratios of 2.8 (2,4-dnitrotoluene), 4.6 (1,3-dinitrobenzene), and 6.2 (RDX). The low ratios by which the benchmark values were exceeded indicate limited potential for these explosives to affect benthic invertebrates even if these compounds were present at concentrations less than the RLs.

Benchmark values were not available for several of the explosive compounds. Excluding nitroglycerin and PETN, the RLs for these compounds were less than or equal to 0.08 mg/kg. These low RLs indicate limited potential for these explosives to be in the pond sediment at levels that could pose an ecological threat. The RLs for nitroglycerin (0.25 – 4 mg/kg) and PETN (0.2 – 0.44 mg/kg) were relatively high. If these two explosives are actually present in the pond, the elevated RLs could have resulted in underestimation of ecological risks.

Surface Water

All of the surface water RLs were less than the ecological benchmark values. Benchmark values were not available for tetryl and 1,3,5-trinitrobenzene. For both compounds, the RI samples had RLs of 0.08 ug/L. This low RL indicates limited potential for either explosive to be present at concentrations that could pose an ecological threat. The analytical sensitivity associated with the surface water samples contributed little to the overall uncertainty.

6.3.8.1 Uncertainty Associated with the Avian Piscivore Evaluation

Although the great blue heron is similar to the three sensitive avian piscivores that could frequent Nike Pond, there are differences among the species that could contribute to uncertainty in the food web analysis. The great blue heron ranges in height from 106 centimeters (cm) to 132 cm (EPA, 1993). The American bittern, black-crowned night heron, and yellow-crowned night heron are much smaller, with approximate heights of 58 – 70 cm for the American bittern, 64 cm for the black-crowned night heron, and 61 cm for the yellow-crowned night heron (EPA, 1993).

Because the normalized food ingestion rate is inversely related to body weight, use of the great blue heron as the representative species could underestimate the potential dose for these smaller members of the heron family. In addition, the American bittern and the two night herons are likely to eat more frogs and other animals that live in the sediment than the great blue heron, which feeds predominantly on fish. Thus, the American bittern and night herons have greater potential to be exposed to sediment contaminants than would be reflected in food web calculations based on the great blue heron.

No studies on the food ingestion rates for the American bittern, black-crowned night heron, or yellow-crowned night heron were found. A food ingestion rate representative of these 3 species was calculated using the allometric equations provided in EPA's Wildlife Exposure Factors Handbook (EPA, 1993). For these equations, it is necessary to know the weight and dietary composition of the target species. Information on the body weight and diet of the American bittern, which is similar in size to the two night herons, was found at the following website:

http://www.epa.gov/region1/ge/thesite/restofriver/reports/final_era/B%20-%20Focus%20Species%20Profiles/EcoRiskProfile_american_bittern.pdf.

This latter reference specified a body weight range of 370 – 500 grams for the American bittern. The low end of this weight range, 370 g, was used in the calculations. The food ingestion rate was estimated from the field metabolic rate calculated with the body weight of 370 grams. The food ingestion rate and water ingestion rate calculations are presented in Table 17 of Appendix G.

The estimated food and water ingestion rates were incorporated into a food web analysis performed in the same manner as described for the great blue heron. Unlike the diet assumed for the great blue heron, the American bittern eats flying insects

To estimate the tissue concentrations of these insects, the recommended BSAFS for flying insects listed in Bechtel-Jacobs (1998b) were used. These BSAFs, which differ from the BSAFs used to estimate benthic invertebrate tissue concentrations, are presented in Table 18 of Appendix G.

The food web calculations are presented in Table 19 of Appendix G. The maximum detected concentration was used as the exposure point concentration for each metal in each medium. For cadmium, mercury, and silver, which were detected in the sediment samples but not the surface water samples, the reporting limit was used as the exposure point concentration for surface water. As shown in Table 19, the ecological quotients for arsenic, cadmium, chromium, copper, nickel, mercury, selenium, silver, and zinc were less than 1, confirming that these nine metals do not pose a threat to the avian piscivore.

The maximum lead concentrations in surface water and sediment resulted in a NOAEL-based ecological quotient of 2 for the American bittern, as compared to the quotient of 1 estimated for the great blue heron. This comparison suggests that use of the great blue heron underestimated potential exposure for the American bittern and two night herons.

On the other hand, use of the maximum sediment concentration as the exposure point concentration for this analysis likely overestimated potential exposure. The majority of the average daily dose estimated for the American bittern was due to lead in sediment. The maximum sediment concentration, 286 mg/kg, was reported for one of the 2006 SI samples. The other SI sample had a concentration of 27.9 mg/kg, or approximately one-tenth the maximum detection. In the 2011 samples, the sediment concentrations were even lower, ranging from 3.1 mg/kg to 9.5 mg/kg.

Because it is unlikely that the American bittern would forage in only one part of Nike Pond, it is overly conservative to assume that this receptor would be exposed solely to the maximum sediment concentration. A 95% UCL could not be calculated because of the size and skewness of the data set. If the average concentration of 44 mg/kg is used as the sediment exposure point concentration, then the NOAEL-based ecological quotient is 0.4 (Table 19). This analysis supports the original conclusion that lead in the Nike Pond sediment is unlikely to affect avian piscivores.

6.3.9 Evaluation of Incremental Samples

The IS results were compared to ecological benchmark values to assess qualitatively the potential ecological threat. The data were screened and the results are presented by sample below.

IS Sample FHRI-01-SO-01 – Post-BIP: Four metals, antimony (0.61 mg/kg), chromium (22.6 mg/kg), lead (29.3 mg/kg), and vanadium (16.2 mg/kg), were found at concentrations above their ecological screening values. The lead and vanadium concentrations were less than the average NJ background values, and the antimony result was less than the Fort Hancock mean background concentration. These three metals appear to reflect background conditions. Thus, any potential ecological risk would be due to natural conditions.

The chromium result was slightly greater than the mean NJ and Fort Hancock background concentrations. The benchmark value used for screening was based on potential effects to earthworms. Efroymson, et al (1997b), who developed the benchmark value, gave this screening value a low confidence rating. USEPA has developed Eco-SSLs for exposure of birds and mammals (USEPA, 2005a). The chromium result was less than the bird Eco-SSL of 26 mg/kg and the mammal Eco-SSL of 34 mg/kg, indicating no threat to these receptors.

In the Ecological Soil Screening Levels for Chromium (USEPA, 2005a), 11 plant studies that meet the study acceptance criteria were identified. Although no observed adverse effect concentration (NOAEC) values from these studies ranged between 20 mg/kg and 138 mg/kg, two studies identified EC_{50} values of 3 mg/kg and 9 mg/kg, and one study identified a lowest observed adverse effect concentration of 15 mg/kg. Although greater than the EC_{50} and LOAEC values, the chromium result is on the low end of the range of NOAECs. Comparison to the various study results suggests limited potential for chromium to affect plants.

Two soil invertebrate studies that met the Eco-SSL guidance criteria were identified in USEPA, 2005a. In both studies, a maximum acceptable toxicant concentration (MATC) of 57 mg/kg, based on reproduction, was determined. The chromium result was less than the MATC, indicating that a threat is not posed to soil invertebrates.

<u>IS Sample FHRI-01-SO-02 – Post-BIP</u>: Six metals, antimony (2.2 mg/kg), chromium (20.4 mg/kg), copper (127 mg/kg), lead (122 mg/kg), mercury (0.09 mg/kg), and vanadium (15 mg/kg), were found at concentrations above their ecological screening values. Lead, mercury, and vanadium concentrations were below the average NJ background values. Any potential risk associated with these metals would reflect background conditions.

Similar to the chromium evaluation for sample FHRI-01-SO-01 PostBIP above, comparison of the chromium concentration (20.4 mg/kg) to the Eco-SSLs (26 mg/kg for birds and 34 mg/kg for mammals), earthworm MATC (57 mg/kg), and various toxicity values for plants indicates limited potential for chromium to pose a threat to ecological receptors.

The antimony result was less than the Eco-SSL for soil invertebrates (USEPA, 2005b) and the plant benchmark value of 5 mg/kg (Efroymson, et al, 1997a). Antimony does not pose a threat to these receptors. The antimony concentration was approximately 8 times the mammal Eco-SSL. The low ratio by which the result exceeded the screening value indicates limited potential for antimony to pose a threat to wildlife.

The copper result was 1.8 times the plant Eco-SSL, 1.6 times the soil invertebrate Eco-SSL, 4.5 times the bird Eco-SSL, and 2.6 times the mammal Eco-SSL (USEPA, 2007). Based on the low ratios by which the screening values were exceeded, there is limited potential for adverse effects to ecological receptors.

<u>IS Sample FHRI-01-SO-03 – Pre-BIP</u>: Five metals, antimony (0.64 mg/kg), chromium (12.7 mg/kg), lead (49 mg/kg), mercury (0.043 mg/kg), and vanadium (10.1 mg/kg), were found at concentrations above their ecological screening values. The lead, mercury, and vanadium concentrations were below the average NJ background values. The chromium result was approximately equal to the average NJ background value. The antimony detection was less than the mean Fort Hancock background concentration. These five metals reflect background conditions.

<u>IS Sample FHRI-01-SO-04 – Post-BIP</u>: Two metals, chromium (2.8 mg/kg) and vanadium (3.8 mg/kg), were found at concentrations above their ecological screening values. Both results were

less than their respective average NJ background concentration, indicating the absence of contamination that could pose an ecological threat at this sample location.

<u>IS Sample FHRI-02-SO-01 – Post-BIP</u>: Six metals, antimony (0.85 mg/kg), chromium (13.9 mg/kg), copper (81.2 mg/kg), lead (40.7 mg/kg), mercury (0.027 mg/kg), and vanadium (15.9 mg/kg), were found at concentrations above their ecological screening values. Lead, mercury, and vanadium concentrations were less than the average NJ background values. The antimony and chromium results were less than the mean Fort Hancock background concentrations. Any threat posed by antimony, chromium, lead, mercury, and vanadium would represent background conditions.

The copper concentration was approximately equal to the soil invertebrate Eco-SSL (80 mg/kg), and was 1.2 times the plant Eco-SSL, 2.9 times the bird Eco-SSL, and 1.7 times the mammal Eco-SSL (USEPA, 2007). Based on the low ratios by which the Eco-SSLs were exceeded, there is limited potential for copper to pose an ecological threat.

<u>IS Sample FHRI-05-SO-01 – Post-BIP</u>: Five metals, antimony (4.4 mg/kg), chromium (23.2 mg/kg), copper (94.4 mg/kg), lead (96.9 mg/kg), and vanadium (17.1 mg/kg), were found at concentrations above their ecological screening values. The lead and vanadium concentrations were less than the average NJ background concentrations. These metals were identified as background constituents.

The antimony detection was less than the benchmark values for plants and terrestrial invertebrates. The sample encompasses a small area in the vicinity of a MEC item that was detonated. Because of the limited area covered by the sample, it is unlikely that a bird or mammal would experience significant exposure to the antimony. For these reasons, the antimony is unlikely to pose an ecological threat.

The chromium result was less than the bird and mammal Eco-SSLs, and the MATC for soil invertebrates (USEPA, 2005a). The detection was on the low end of the range of NOAECs identified in USEPA, 2005a. These comparisons indicate limited potential for chromium to pose an ecological threat.

The copper result was 1.4 times the plant Eco-SSL, 1.2 times the soil invertebrate Eco-SSL, 3.4 times the bird Eco-SSL, and twice the mammal Eco-SSL (USEPA, 2007). Based on the low ratios by which the Eco-SSLs were exceeded, there is limited potential for copper to pose an ecological threat.

<u>IS Sample FHRI-05-SO-02 – Post-BIP</u>: Six metals, antimony (2 mg/kg), chromium (20.9 mg/kg), copper (115 mg/kg), lead (75.8 mg/kg), mercury (0.15 mg/kg), and vanadium (16 mg/kg), were found at concentrations above their ecological screening values. Lead, mercury, and vanadium concentrations were less than the average NJ background levels.

The antimony result was less than the Eco-SSL of 78 mg/kg for soil invertebrates (USEPA, 2005b) and the plant benchmark value of 5 mg/kg (Efroymson, et al, 1997b). Antimony does not pose a threat to these receptors. The antimony concentration was 7.4 times the mammal Eco-SSL. The low ratio by which the result exceeded the screening value indicates limited potential for antimony to pose a threat to wildlife.

Similar to the chromium evaluation for sample FHRI-01-SO-01 PostBIP, comparison of the chromium concentration (20.9 mg/kg) to the Eco-SSLs (26 mg/kg for birds and 34 mg/kg for mammals), earthworm MATC (57 mg/kg), and various toxicity values for plants indicates limited potential for chromium to pose a threat to ecological receptors.

The copper result was 1.6 times the plant Eco-SSL, 1.4 times the soil invertebrate Eco-SSL, 4.1 times the bird Eco-SSL, and 2.3 times the mammal Eco-SSL (USEPA, 2007). Based on the low ratios by which the Eco-SSLs were exceeded, there is limited potential for copper to pose an ecological threat.

In summary, evaluation of the incremental sample results indicates limited potential for possible contaminants to pose an ecological threat.

6.3.10 Ecological Risk Assessment Summary and Conclusions

The SLERA evaluated potential risks to terrestrial, benthic invertebrate, and aquatic receptors that might contact the site soil, sediment, and surface water, respectively. Both direct exposure and indirect exposure via the food web were considered. No ecological threats were identified for the incremental sample locations, MRS-1, MRS-3, MRS-5, MRS-6, MRS-7, and Nike Pond. At the B003 Area, antimony, copper, lead, and selenium could pose a threat to wildlife receptors. In addition, antimony, arsenic, copper, lead, and thallium contamination at B003 may pose a threat to the plant and/or soil invertebrate communities. However, these conclusions are based largely on a single soil sample (out of 3 samples collected from the B003 Area as part of the SI in 2006) that contained the maximum detections of these metals.

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7.0 CONTAMINANT FATE AND TRANSPORT FOR MUNITIONS CONSTITUENTS

In order to completely characterize the site, an evaluation of the environmental fate and transport of chemicals of concern (COCs) identified in the human health and ecological risk assessments (Section 6.0) was performed. This chapter discusses the fate and transport mechanisms potentially affecting releases and distribution of constituents and examines how these mechanisms affect migration of the constituents. Specifically, the subsections below detail the potential routes of constituent transport and provide information on the persistence of identified constituents based on physical, chemical and biological factors affecting fate and transport.

Based on conclusions from the human health and ecological risk assessments (Section 6.0), RI and SI sampling results for all MRSs confirm that there are no risks posed by metals or explosives compounds; therefore, no munitions constituents were identified as COCs for any of the MRSs. There were no explosives compounds found above the detection limits in any soil samples (from MRSs 1, 3, 5, 6 and 7), surface and sediment samples (from the Nike Pond, within MRS-5), or groundwater samples (from representative wells across Fort Hancock). As discussed in Section 6.0, various metals were detected in soil and groundwater samples; however, none were found at levels inconsistent with background concentrations. Although metals were detected above ecological screening criteria in the surface and sediment samples, no ecological risks were identified in the risk assessment.

However, the risk assessments identify several metals from the B003 Area detected during the SI as COCs for this RI. These metals include antimony, arsenic, copper, lead, selenium, and thallium. No MEC was found in the B003 Area during the RI (only MD) and no explosives compounds related to the B003 Area were found above detection limits in the SI samples. Therefore, the metals of concern within the B003 Area are the only COCs identified for this RI and were the only MC for which contaminant fate and transport analysis was performed.

7.1 Potential Contaminant Sources

The B003 Area is located in MRS-1, adjacent to the new proving battery firing point. Based on the 1998 EE/CA investigation, the B003 Area appears to have been a former ordnance disposal area and is known to have contained MEC and MD. Three surface soil samples were collected in the B003 Area in 2006 for the SI. Metals contamination, as described in the risk assessments, is largely due to a single soil sample (out of three samples collected from the B003 Area as part of the 2006 SI) that contained the maximum detections of these metals. The soil sample (FHK-NP-SS-06-03) was located approximately 150 ft south of the B003 grid that contained the MEC and MD. The source of the contamination in FHK-NP-SS-06-03 is not known. However, given the findings in this area, the MEC and MD may be the potential source of metals contamination.

7.2 Potential Routes of Migration

The following subsections present a discussion of fate and transport mechanisms that affect the distribution and transport of soil contaminated with metals from the B003 Area. Migration pathways provide a route for the metals of concern to be transported across and between media. Migration pathways can be naturally occurring or man-made. Potential migration pathways for B003 Area metals include airborne, soil and sediment, surface water, and groundwater.

7.2.1 Airborne Transport

Movement of surface soil particulates from metals contaminated soils via atmospheric wind is considered a potential transport mechanism. Such particulate transport is generally limited to particle size, wind speeds and other site-specific conditions. The surficial soils at the B003 Area consist mainly of beach and dune sands. However, there are areas of significant vegetation to retard the airborne transport. Metals contaminated soils could be transported via wind across Fort Hancock, but it is unlikely due to the mature vegetation and ground cover in the B003 Area.

7.2.2 Soil and Sediment Transport

Typically, surface and subsurface soil are not considered transport media; however, if sufficiently impacted (e.g., severe erosion), soils may affect the final transportation and disposition of identified metals. Precipitation could transport metals of concern, via direct infiltration, from surface soil and sediment to subsurface soils and groundwater. The likelihood of this occurring is dependent on multiple fate processes and factors, as discussed under Section 7.3, Contaminant Persistence. Lateral transport of metals contaminated soils from the B003 Area is also possible via surface runoff; however, it is unlikely to occur (except during intense rainfall events) due to high infiltration and mature vegetation in the B003 Area.

7.2.3 Surface Water Transport

Other than the Atlantic Ocean, there are no surface water bodies located near or in the vicinity of the B003 Area. Except during intense rainfall events, infiltration is high and surface runoff is minimal due to the sandy soils. Lateral transport of metals contaminated soil from the B003 Area via surface water tidal action is possible during extreme storm surge events. While typically this transport is not significant due to high infiltration, mature vegetation, and the lengthy distance from the B003 Area to the ocean, recent extreme storm events indicate this transport can occur. Surface water could potentially transport metals (vertically) to subsurface soils and shallow groundwater via direct infiltration; however, the likelihood is low due to the distance from the B003 Area to the Atlantic Ocean. In the event of extreme storm surges, dilution of the metals in this small area of potential contamination would occur, having the effect of minimizing contaminant concentrations over the exposure unit.

7.2.4 Groundwater Transport

Groundwater recharge at Fort Hancock, including the B003 Area, is predominantly from precipitation, flooding and snowmelt infiltration. As water filters through the surface soil and overburden into the soil pores, metal constituents could potentially be transported into the groundwater from areas of high hydraulic head to areas of low hydraulic head. The likelihood of B003 Area metals transport into the groundwater is dependent on multiple fate processes and factors, as discussed under Section 7.3, Contaminant Persistence.

During extended dry periods, shallow groundwater may percolate upward into the sandy soils and carry B003 Area metals of concern back down to the groundwater. The likelihood of metals transport via groundwater percolation is rare and is also dependent on multiple fate processes and factors, as discussed under Section 7.3, Contaminant Persistence.

Drinking water for the entire Sandy Hook peninsula is supplied by one well approximately 880 feet deep completed in a confined aquifer; surrounding boroughs receive drinking water from other public community supply wells. The Sandy Hook drinking water supply has tested safe for consumption, with metals concentrations sufficiently removed in the treatment process. The aquifers supplying drinking water are significantly deep and the transport of B003 metals of concern to these deep groundwater sources is highly unlikely.

7.3 Constituent Persistence

As previously discussed, contaminant fate and transport analysis was performed only for the following six metals of concern within the B003 Area: antimony, arsenic, copper, lead, selenium, and thallium. This subsection explains physical and chemical processes and factors that affect the persistence of the B003 Area COC metals in soil and groundwater. Since the airborne transport of metals contaminated soils is unlikely due to mature vegetation and ground cover in the B003 Area, the persistence of B003 metals in air particles is not addressed in this section.

Movement of metals through soils is dependent on the chemical properties controlling speciation, the presence of ligands that control complexation of metals within pore water (and groundwater) and adsorption onto mineral surfaces, and the rate of water flux through the soil. Metals are lost from the soil by leaching into ground water. The potential for transport of metal analytes in the subsurface is based upon analyte specific affinity to soil and groundwater. Soil factors affecting transport dynamics include soil-water chemistry and charge deficiency on adsorbent surfaces, such as soil and sediment. To neutralize the surface charge, an accumulation of ions near the soil-groundwater interface is required. Factors including geology, soil chemistry, pH, redox potential, ionic strength, dominant cations and ligands also enhance or diminish the mobility of a particular metal analyte. Generally, the solubility of metals tends to increase proportionate to increased acidity, and conversely under alkaline conditions.

There are numerous natural materials that interact with water. Metal sorption is affected primarily by physical and geochemical processes (i.e., oxidation, adsorption, precipitation and complexation). Generally, the sorption coefficient for a metal is indicative of the relative affinity of a metal to soil, and ultimately the mobility of the metal. Physical adsorption is due to surface charges which attract ionic species of the opposite charge. Hydrous oxides may also promote the sorption of metals. Metal ions sorbed to these surfaces become precipitated with the hydrous oxides. Chemical processes for adsorption include ion exchanges, precipitation, solid-state diffusion, and isomorphic substitution. Organic matter may also result in metals sorbing to soil and sediment making them insoluble in groundwater.

The transport pathways in groundwater include advection, hydrodynamic dispersion, diffusion, and sorption.

- Advection is the process by which solutes are transported via flowing fluids, such as groundwater. Transport under this scenario is directly proportional to the rate of groundwater flow and proximal to the direction of the groundwater flow.
- Hydrodynamic dispersion is the process of horizontal and vertical aqueous mixing of a solute being advected, resulting in a blended zone between adjacent aqueous solutions or displaced aqueous solutions.
- Diffusion and/or mechanical dispersion facilitate the mixing of the two zones.
- Sorption of metals in aquatic systems is generally dependent on the processes described below. In addition to these factors, sorption is influenced by interactions with natural

organic matter, changes in pH, oxidation potential, salinity, concentrations of competing ions, the nature of sorbent phases and their surface areas, and surface site densities.

- Speciation/complexation - the distribution of a given constituent among its possible chemical forms, including metal complexes, which have differing tendencies to be adsorbed or desorbed;
- Precipitation - the process by which dissolved species exceed the solubility limits of their solids, so that some of the species precipitate from solution;
- Colloid formation - results in metals being sorbed or coprecipitated with colloidal-sized particles;
- Biofixation - occurs when biological processes (usually involving microorganisms or plants) result in the binding of metals to solid materials;

The following information presents a general discussion of the properties of the COC metals in the B003 Area with regard to persistence in the environment and the potential for inter-media transport and migration.

7.3.1 Antimony

Elemental antimony is relatively short-lived in the natural environment undergoing oxidation reactions to form antimony oxides and trihalides. Although not demonstrated, antimony may undergo biological methylation (forming organometals) as do those compounds surrounding it in the periodic table. Antimony oxides and trihalides are expected to volatilize readily, with SbCl3 releasing HCl gas to the atmosphere when in the presence of moisture (ATSDR, 1990a). Antimony oxides are also expected to undergo photoreduction in aqueous environments. Organic antimony compounds are relatively mobile in all environments, while inorganic antimony compounds tend to be only slightly soluble or decompose in water (ATSDR, 1990a). Antimony, is not expected to bioconcentrate appreciably in fish or aquatic organisms (ATSDR, 1990a).

7.3.2 Arsenic

Elemental arsenic is extremely persistent in both water and soil. Environmental fate processes may transform one arsenic compound to another; however, arsenic itself is not degraded. Soluble forms of arsenic tend to be quite mobile in water, while less soluble species adsorb to clay or soil particles. Microorganisms in soils, sediments, and water can reduce and methylate arsenic to yield methyl arsines, which volatilize and enter the atmosphere. These forms then undergo oxidation to become methyl arsonic acids and are ultimately transformed back to inorganic arsenic (ATSDR, 1991).

Bioconcentration of arsenic occurs in aquatic organisms, primarily in algae and lower invertebrates. Biomagnification in aquatic food chains does not appear to be significant, although some fish and invertebrates contain high levels of arsenic compounds which are relatively inert toxicologically. Plants may accumulate arsenic, subject to various factors including soil arsenic concentration, plant type, and soil characteristics (ATSDR, 1991).

7.3.3 Copper

Copper is a naturally occurring, highly reactive metal, very ductile and has highly thermal and electrical conductive properties. Copper is rarely found or used in a pure form and is used in MEC in the form of alloys due to its light weight, conductive properties, and resistance to corrosion. Copper is a metal that is used in the production of various projectiles, fuzes and cartridge magazines. The properties of copper allow for its wide use as a component of metal alloys. Copper is dispersed throughout the atmosphere primarily as a result of anthropogenic activities. Environmental fate processes may transform one copper compound to another; however, copper itself is not degraded. Most of the copper in the atmosphere occurs in the aerosol form, and long-distance transport may occur. Wet or dry deposition is expected to be the primary fate process in air.

Several processes determine the fate of copper in aquatic environments: formation of complexes, especially with humic substances; sorption to hydrous metal oxides, clays, and organic materials; and bioaccumulation. Organic complexes of copper are more easily adsorbed on clay and other surfaces than the free form. The aquatic fate of copper is highly dependent on factors such as pH, oxidation-reduction potential, concentration of organic matter, and the presence of other metals. In regard to the latter, it has been demonstrated that co-precipitation of copper with hydrous oxides effectively scavenges copper from solution, although in most surface waters organic materials prevail over inorganic ions in complexing copper (USEPA, 1979).

Generally, copper is considered to be among the more mobile of the heavy metals in surface environments. Seasonal fluctuations have been observed in surface water copper concentrations, with higher levels in fall and winter, and lower levels in the spring and summer. It is not expected to volatilize from water. Since copper is an essential nutrient, it is strongly accumulated by all plants and animals, but is probably not biomagnified (USEPA, 1979). The degree of persistence of copper in soil depends on the soil characteristics and the forms of copper present. For example, in soils of low organic content, soluble copper compounds may move into groundwater at a significant rate. On the other hand, the presence of organic complexing agents may restrict movement in soil, and copper may be immobilized in the form of various inorganic complexes. It is not expected to volatilize from soil.

Copper is characterized by a high flow rate in soils and a lower adsorption rate in soils; therefore allowing copper to be transported to, and within, groundwater at a faster rate than other comparable metals. Due to these characteristics, copper can be transported greater distances and depths in comparison to other metals. Copper adsorption rates are generally uniform in the surface and shallow soils (Sharma et al., 2009).

7.3.4 Lead

Lead in the environment can be from anthropogenic and natural sources. Lead is a naturally occurring bluish-gray metal found in small quantities in the environment. Metallic lead does not dissolve in water and readily interacts with other constituents to form lead compounds; however, organic lead does dissolve readily in water. Based on laboratory analysis and the likely source of lead, MEC related components, lead concentrations at the site are of the inorganic form. Lead has historically been a vital component of all elements of ammunition and MEC.

Lead is extremely persistent in both water and soil. Environmental fate processes may transform one lead compound to another; however, lead itself is not degraded. It is largely associated with suspended solids and sediments in aquatic systems, and it occurs in relatively immobile forms in soil. In natural water systems, lead in solution depends primarily on pH, temperature, and salt content (ATSDR, 1993). Lead may also exist in the form of sulfates, hydroxides, phosphates, chlorides, and carbonates (ATSDR, 1993; HSDB, 1999). Lead is most bioavailable in waters under conditions of low pH, organic content, salts, and particulates (Eisler, R., 1988).

In soils, lead fate primarily depends on organic matter content, specific or exchange adsorption at mineral interfaces, and the formation of precipitates, chelates, and organic-metal complexes (ATSDR, 1993). Lead sorbs to organic matter in soil and is not subject to leaching. However, lead may enter surface waters via erosion of soil particles (ATSDR, 1993; HSDB, 1999). Lead which has been released to soils may become airborne as a result of fugitive dust generation. Lead particles are removed from air via wet and/or dry deposition (ATSDR, 1993). Tetraethyl lead may occur in the vapor phase (ATSDR, 1993).

Tetraethyl and tetramethyl lead exist primarily in the vapor phase and decompose rapidly under UV radiation. Tetramethyl lead may also form in anaerobic sediments via microorganisms and subsequently volatilize into surrounding water and air. Anthropogenic sources of organo-lead compounds occur primarily in the aqueous environment (Eisler, R., 1988). Plants and animals bioconcentrate lead, but there no evidence of biomagnification (ATSDR, 1993).

Approximately 40 percent to 60 percent of the human exposure to lead is via inhalation and ingestion (ASTDR, 2007). The most common route of exposure for adults is via inhalation, for children it is ingestion. Lead is characterized as having a relatively higher and stronger sorption when compared to other heavy metals, such as zinc. In order to become mobile, lead must first be oxidized; lead mobility in soil is most dominantly influenced by adsorption and precipitation (Sittig, 1985). Lead mobility in soil is severely restricted when ORP conditions are less than 0 mV; the average ORP observed at the site is 40 mV.

7.3.5 Selenium

The behavior of selenium in the environment is dependent upon its oxidation state, and the behavior of the chemical compounds formed as a result of the differing oxidation states. In addition, the oxidation state of selenium in the environment is dependent upon a number of environmental factors, including pH, Eh, and biological activity. For releases of selenium to soils, pH and Eh will be the primary determining factors for its fate and transport. Elemental and/or inorganic selenium may undergo microbial methylation (to dimethyl selenide and dimethyl deselenide), ultimately being volatilized to the atmosphere. Acidic soil conditions favor the predominance of selenides. Selenides are insoluble and are expected to be immobile in the soils. Neutral to alkaline soil conditions favor the predominance of selenates. Selenates are expected to be very mobile in soils, given their high solubility and low sorption potential, and represent a potential for leaching to unprotected groundwaters. For water-soluble selenium compounds (i.e., selenates), terrestrial plant uptake represents a removal/transport mechanism of concern, but will be influenced by a variety of environmental factors (e.g., pH, soil type, reduction oxidation (redox) potentials).

Selenium released to surface waters is expected to be found in the form of salts of selenic and selenious acids. Salts of selenic acid (such as sodium selenate) are generally found in aerobic, alkaline waters, and are expected to be highly mobile in the aquatic environment. Salts of selenious acid (selenite salts) are found in neutral to acidic waters, and show less environmental mobility than do selenate salts. Under acidic conditions, however, selenite is readily reduced to elemental selenium; selenate, as well, is converted to elemental selenium, but more slowly. Elemental selenium will be stable over a wide range of pH and redox conditions. Aquatic organisms, however, will convert selenium to selenoamino acids and, subsequently, methylated selenium compounds. Neither metabolic product is expected to exist long in the aquatic environment, with the methylated forms volatilizing rapidly to the atmosphere. Selenium in the aquatic environment has been demonstrated to bioaccumulate (logBAF = 3.60), bioconcentrate (logBCF = 3.27), and, potentially, biomagnify in aquatic organisms.

7.3.6 Thallium

Elemental thallium is a bluish-white, very soft, inelastic, easily fusible, heavy metal. It will oxidize superficially in air forming a coat of thallium oxide. It will react with nitric and/or sulfuric acids, but only slightly so with hydrochloric acid (Merck, 1989). Thallium exists in either monovalent (thallous) or trivalent (thallic) forms; thallous being much more common. Thallic salts are readily reduced to thallous salts; virtually all are chemically reactive with air and moisture. Volatilization of thallium and its salts is not expected to occur at ambient temperatures and pressures. Elemental thallium is insoluble in water; thallium salts show a moderate to high degree of solubility (i.e.: thallium sulfide exhibiting solubility to 200 mg/L; and thallium fluoride exhibiting solubility to 780 g/L) (USEPA, 1980). Therefore, thallium is expected to be relatively mobile in aquatic environments and/or moist-to-wet soils. Thallium shows some tendency to bioconcentrate in aquatic organisms (ATSDR, 1990e).

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8.0 SUMMARY AND CONCLUSIONS

8.1 Summary

This section summarizes the key findings from Sections 5.0 and 6.0.

8.1.1 Nature and Extent of Contamination

8.1.1.1 MC

Environmental sampling of soil, surface water, sediment, and groundwater for MC was completed during the Fort Hancock RI, as described in Section 4.0. MC findings were presented in Section 5.0. Human health and ecological risk assessments, which included the sample results from the 2007 SI, were presented in Section 6.0. The MC findings are summarized in the following paragraphs.

IS soil samples associated with BIP activities were collected during the RI and analyzed for metals and explosives. No explosives compounds above the detection limits were found in any sample. Various metals were detected, but none of the metals were found at levels inconsistent with background concentrations. Analysis of discrete soil samples from MRS-7 found no explosives compounds above the detection limits in any sample. Various metals were detected, but none of the metals were found at levels inconsistent with background concentrations. A "hot spot" analysis of soil sample results indicated the absence of potential contamination that could pose a threat to the underlying groundwater. Based on this evaluation, the need for an expanded groundwater investigation was not indicated.

For the RI, surface water and co-located sediment samples were collected from Nike Pond (MRS-5) and analyzed for metals and explosives. No explosives compounds were found above the detection limits in any sample. Various metals were detected.

Groundwater samples were collected from five existing wells during the RI and analyzed for metals and explosives. No explosives compounds were found above the detection limits in any sample. Various metals were detected.

Section 8.1.2 below summarizes the results with regard to whether these findings represent risks posed to human health or the environment.

8.1.1.2 MEC/MD

A comprehensive statistically based DGM and intrusive investigation of land-based MRSs was conducted at Fort Hancock, including approximately 38 miles of transects, 52 clusters, 87 grids, and nearly 5,000 anomalies intrusively investigated.

In addition to the land-based MRSs, a comprehensive statistically based DGM and intrusive investigation of marine-based MRS-8 was conducted, including 49,600 linear feet or 9.4 miles of usable data acquired, covering approximately 9 acres, and 51 anomalies intrusively investigated.

Seven MEC items and 65 MD items were found in the land-based MRSs. Some of these items were found on the surface and some were found in the subsurface. No MEC or MD were found in marine MRS-8.

Table 8-1 summarizes the MEC and MD finds per area of investigation. These are also shown in Figures A-5-1 and A-5-2.

Table 8-1. MEC/MD Finds Per Area of Investigation		
MRS or Area of Investigation	**MEC Items**	**MD Items**
MRS-1	3	23
B003 Area	0	16
MRS-2	1	10
MRS-3	0	5
MRS-4	2	5
MRS-5	1	4
MRS-6	0	0
MRS-7	0	0
MRS-8	0	0
PAOI Kingman-Mills	0	0
PAOI 9-Gun	0	2
TOTALS	**7**	**65**

The results of the DGM and intrusive investigations indicate that certain areas containing a concentration of metallic anomalies (clusters) within the MRSs have a higher likelihood of a human or ecological receptor encountering MEC or MD than others.

In these clusters, MEC/MD Hazard Areas were identified as areas of focus within the MRS. These MEC/MD Hazard Areas provide an approach to reducing the overall MRS footprint for potential future actions. As defined, the MEC/MD Hazard Areas represent a "moderate to high" probability of encountering MEC/MD, while the remainder of the MRS represents a "low" probability of encountering MEC/MD. Table 8-2 summarizes the MEC/MD Hazard Areas per location; these areas are also shown in Figures A-5-6 through A-5-10.

Please note that while the hypothesis used in the UXO Estimator statistical design of the investigation was based on 5 UXO/acre (see DQO Table 3-2a and Section 4.1.3.3), areas categorized as "low probability", where no MEC or MD was found, and where the coverage goal was not achieved, could still contain MEC or MD items.

The B003 Area within MEC/MD Hazard Area 1-A of MRS-1, represents a special case. During the 1998 EE/CA investigation, several MEC items were found in grid B003; however, not all of the anomalies, some of which may have been MEC, were excavated. The EE/CA described this area as an ordnance disposal area, recommending a removal action. The intent of the RI effort for the B003 Area was to determine the extent of the B003 EE/CA grid by excavating all anomalies found on the closely spaced transects. Only MD was found in the B003 Area during this RI (no MEC). While MD is scattered around the 30m x 30m EE/CA B003 grid, the MEC items from the EE/CA investigation appear to be limited to the eastern half of grid B003, and that appears to be the extent of MEC contamination associated with this previously defined disposal area.

	Table 8-2. MEC/MD Hazard Areas		
MRS	**NPS Excluded Acreage**	**MEC/MD Hazard Area**	**Probability of Encountering MEC/MD**
MRS-1	1.4	1A*	Moderate to High
		1B	Moderate to High
MRS-2	15.5	2A	Moderate to High
MRS-3	3.5	3A	Moderate to High
		3B	Moderate to High
MRS-4	25.7	4A	Moderate to High
MRS-5	86.5	5A	Moderate to High
		5B	Moderate to High
PAOI-9 Gun	None	PAOI-9 Gun-A	Moderate to High

* Includes the B003 Area.

Approximately 83% (24.2 of 29 acres) of MRS-7 was excluded from investigation by NPS, and could not be investigated in a systematic way. This lessened the ability to provide statistically supported conclusions related to this MRS, and therefore, no conclusions can be drawn about the presence or absence of MEC or MD in the MRS-7 areas denied access by NPS.

This also applies to other areas excluded from investigation by NPS. That is, where little or no DGM coverage was obtained, no conclusions can be drawn about the presence or absence of MEC or MD in the areas denied access by NPS.

8.1.2 Risk Assessment

The HHRA evaluated the current and potential future exposure of receptors to site media. The assessment considered the contributions from background constituents in addition to the potential effects associated with the site contaminants. This evaluation demonstrated that soil at MRS-1, MRS-3, MRS-5, MRS-6, and MRS-7 does not pose a threat to human health. The sediment and surface water at Nike Pond (within MRS-5) does not pose a threat to human health. At the B003 Area (within MRS-1), arsenic and lead in soil could potentially pose a threat to human health. However, these conclusions are based largely on a single soil sample (out of 3 samples collected from the B003 Area as part of the SI in 2006) that contained the maximum detections of these metals. The source of the contamination in that sample is not known. Figure A-5-5 delineates a 2.2 acre potential MC area of concern footprint that includes the three sample locations with the B003 EE/CA grid at its center.

Evaluation of the IS data associated with BIP activities indicated detections of metals in the vicinity of the BIP locations, but the potential contaminants did not pose a threat to human health based on comparison to the residential soil RSLs or background.

There were two groundwater COPCs: arsenic and manganese. The manganese did not pose a threat to human health. For arsenic, the cancer and non-cancer risk exceeded the acceptable levels. However, a risk management decision of no further action with respect to the groundwater is justified based on the fact that the maximum detection was from a single well located in an area where arsenic was at background levels, the concentrations in groundwater were consistent with the range of typical arsenic concentrations in groundwater in New Jersey, and the shallow groundwater is not currently used for any purpose (future use of the shallow groundwater as a potable water supply is extremely unlikely).

The ecological risk assessment evaluated potential risks to terrestrial, benthic invertebrate, and aquatic receptors that might contact the site soil, sediment, and surface water. No ecological threats were identified for MRS-1, MRS-3, MRS-5, MRS-6, MRS-7, and Nike Pond. At the B003 Area, based largely on one soil sample, antimony, copper, lead, and selenium could pose a threat to wildlife receptors. In addition, based on the same soil sample, antimony, arsenic, copper, lead, and thallium contamination at the B003 Area may pose a threat to the plant and/or soil invertebrate communities.

In accordance with the approved Work Plan approach, no environmental samples were collected during the RI in MRS-2, MRS-4, and MRS-8, because no breached MEC, visible evidence of energetics, or areas of significant MD were encountered. No samples were collected in these areas during the 2007 SI. Therefore, no quantitative risk assessment was performed for these MRSs. However, groundwater findings, as discussed above, apply to the entire site. Table 8-3 summarizes the risk assessment findings.

Table 8-3. Summary of Risk Assessment Findings

MRS	Risk Driver	
	Human Health	Ecological
B003	Metals in Soil (As, Pb) for Human Receptors	Metals in Soil (As, Sb, Cu, Pb, Se, Tl) for Ecological Receptors
MRS-1	None	None
MRS-3	None	None
MRS-5	None	None
MRS-6	None	None
MRS-7	None	None

8.2 Conclusions

Nature and extent of MC and MEC has been characterized as described above. Human health and ecological risks have been assessed. Areas of focus (MEC/MD Hazard Areas) have been delineated based on MEC/MD densities. Table 8-4 presents these findings in a single table, indicating acreages and MEC/MD densities, probabilities of encountering MEC/MD in the MRSs, and summarizing the overall conclusions with regard to MC risks and MEC/MD hazards present at the site.

In addition to the findings summarized in Table 8-4, the potential human health and ecological risks posed by MC found in the B003 Area soil, as described in Section 8.1.2, may warrant additional investigation. It is recommended that additional soil sampling be conducted to determine the extent and source of metals contamination in the potential MC area of concern delineated on Figure A-5-5.

With regard to the portion of MRS-7 that was excluded by NPS and could not be fully investigated, the 1998 EE/CA recommended a removal action in a 16-acre area centered on the former storehouse that contained the Livens projectiles and which caught fire in 1927. This is essentially a smaller diameter circle within the current MRS-7 footprint. Given this past history, it is recommended that the NPS excluded portion of MRS-7 (24.2 of 29 acres) be further investigated using DGM and anomaly excavations to determine the nature and extent of MEC/MD, and to identify possible MEC/MD Hazard Areas.

Finally, please note that the need for additional soil sampling at B003 will be addressed in an Addendum to this RI report. The Addendum will evaluate the new sample data and revise the human health and ecological risk assessments of the B003 area, as appropriate.

USACE has further determined that this Addendum will be the appropriate document to present the Munitions Response Site Prioritization Protocol (MRSPP) evaluations and MEC Hazard Assessments (MEC HA). The MRSPP is a required tool used by the Department of Defense to rank sites for further action. The MEC HA is a tool used to assess potential explosive hazards to human receptors at the MRSs. These evaluations will be conducted for revised MRSs that will be delineated based on the results of the RI.

Table 8-4. Summary of Findings						
MRS	**MEC/MD Hazard Area or Area of Focus**	**Acreage**		**MEC Density (item/acre)**	**Potential Concern**	
		Total MRS	**Area of Focus**		**MC**	**MEC/MD\1**
MRS-1	B003 Area	99	2.24	NA	Metals in Soil for Human and Ecological Receptors	\2
	1A		28.89	19.76	None	Moderate to High
	1B		1.51	1.97	None	Moderate to High
MRS-2	2A	151	39.0	2.03	None	Moderate to High
MRS-3	3A	89	0.92	3.26	None	Moderate to High
	3B		1.07	3.41	None	Moderate to High
MRS-4	4A	73	5.15	5.93	None	Moderate to High
MRS-5	5A	205	3.92	1.49	None	Moderate to High
	5B		2.15	8.23	None	Moderate to High
MRS-6	None	90	NA	NA	None	Low
MRS-7	NPS Excluded Portion\3	29	24.2	\3	None	\3
	Investigated Portion\4		4.8	NA	None	Low
MRS-8	None	154	NA	NA	None	Low
PAOI 9 Gun	PAOI-9 Gun-A	8.45	1.19	NA	None	Moderate to High
PAOI Kingman-Mills	None	19.45	NA	NA	None	Low

\1 – Probability of encountering MEC/MD

\2 – MEC risk driver for B003 included in MEC/MD Hazard Area-1A

\3 – This portion of MRS-7 could not be fully investigated for MEC/MD presence due to significant NPS excluded acreage. However, it was fully investigated for MC.

\4 – This portion of MRS-7 was fully investigated

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Appendix A: Figures

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Appendix B: Digital Geophysical Mapping Data

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Appendix B-1:
Equipment Verification Checklists

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Appendix B-2:

G-858 Daily QC Test Results (provided on CD only)

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Appendix B-3:

Transects, Anomalies, and Clusters by MRS

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Appendix B-4:

Clusters, Grid Locations, and Coverage by MRS

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Appendix B-5:

Vertical Gradient and Analytic Signal Maps by Grid

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Appendix B-6:

Field Data Sheets

NOTE: The part 1 field effort did not include field sketches. Information was compiled from the log books and typed on the sheets. For the Part 2 field effort, the actual field sheets with sketches are included.

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Appendix B-7:

Marine IVS Maps

NOTE: The following maps show the background data from the TVG with the selected IVS location. The IVS was installed as a quality control measure for marine data collection in MRS-8. The approximate location of the IVS was selected based on the location of shallow water near the Coast Guard Dock on the west side of the peninsula.

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Appendix B-8:

Marine Repeat Line

NOTE: Appendix B-8 shows the repeatability of data collected with the G-882 TVG in the production area for a segment of marine Transects 3A and 3B of MRS-8. The marine repeat line shown indicates that the responses are generally similar, and any differences are likely caused by a difference in sensor altitude on the two passes.

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Appendix B-9:

Bathymetric Map and Sidescan Sonar Maps and Report

NOTE: The following documents were prepared by Spencer Oceanographic Services, Inc. (SOS), a subcontractor of VRHabilis, as part of the investigation of marine MRS-8. The hydrographic data was used to refine locations of Transects 2 and 3 in the marine investigation described in Section 4.0 of this report. The sidescan data was acquired at the same time in order to map obstructions, which would be avoided to prevent damage to the G-882 TVG.

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Appendix C: MPPEH and MEC Documentation

Appendix C-1. SUXOS Reports
Appendix C-2. Dig Sheets - Grids (All MRSs) + B003
Appendix C-3. Dig Sheets – MRS-8 Marine Survey (Transect 1, 2, 3A, 3B)
Appendix C-4. MEC Photos
Appendix C-5. MPPEH-MEC Accountability Log
Appendix C-6. Form 1348s

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Appendix C-1:
SUXOS Daily Reports

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Appendix C-2:

Dig Sheets - Grids (All MRSs)

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Appendix C-3:
Dig Sheets – MRS-8 Marine Survey

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Appendix C-4:
MEC Photos

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Appendix C-5:
MPPEH-MEC Accountability Log

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Appendix C-6:
Form 1348s

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Appendix D: Surveyor Report

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Appendix E: Groundwater Well Data

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Appendix F: Analytical Data

Appendix F-1. Data Summary Tables
Appendix F-2. Analytical Data Packages and Electronic Data Deliverables (provided on CD only)
Appendix F-3. Data Quality Assessment - Validation Reports

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Appendix F-1:

Data Summary Tables

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Appendix F-2:
Analytical Data Packages and Electronic Data Deliverables
(Provided on CD only)

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Appendix F-3:

Data Quality Assessment - Validation Reports

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Appendix G: Risk Assessment - Supporting Tables

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Appendix G-1:
Human Health Risk Assessment Tables

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Appendix G-2:
Screening Level Ecological Risk Assessment Tables

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Appendix H: Photo Log

Appendix H-1. Miscellaneous Activity by MRS
Appendix H-2. Environmental Sampling
Appendix H-3. Marine

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Appendix H-1:
Miscellaneous Activity by MRS

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Appendix H-2:
Environmental Sampling

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Appendix H-3:
Marine Activities

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Appendix I: NPS General Management Plan Environmental Impact Statement

(presented on CD only)