Final
Remedial Investigation Report, Culebra Island Site Puerto Rico

Terrestrial Areas of:

Artillery Firing Area (MRS 06) – Project No. I02PR006806
Cayo Norte Impact Area (MRS 08) – Project No. I02PR006808
Soldado Point Mortar and Bombing Area (MRS 09) – Project No. I02PR006809
Defensive Firing Area No. 1 (MRS 10) – Project No. I02PR006810
Defensive Firing Area No. 2 (MRS 11) – Project No. I02PR006811
Cayo Luis Peña Impact Area (MRS 13) – Project No. I02PR006813

Prepared for:

U.S. Army Engineering & Support Center, Huntsville
And
U.S. Army Corps of Engineers, Jacksonville District

Contract No. W912DY-04-D-0006
Task Order No. 0022
Property No. I02PR006800
Geographical District: Jacksonville

FINAL
April 2017

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Remedial Investigation Report
Culebra Island Site, Puerto Rico
FUDS Project No. I02PR0068
Contract: W912DY-04-D-0006, Task Order: 0022
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FUDS Property No. I02PR0068

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April 2017

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ACRONYMS AND ABBREVIATIONS

AAA	Autoridad de Acueductos y Alcantarillados
ABP	Agent Breakdown Product
AC	hydrogen cyanide (also frequently abbreviated as HCN)
AEA	Atomic Energy Act
AER	Ammunition and Explosives
APPL	Agricultural Priority Pollutants Laboratory, Inc.
ARAR	Applicable or Relevant and Appropriate Requirement
ASR	archives search report
ATSDR	Agency for Toxic Substances and Data Registry
bgs	below ground surface
BSI	Blind Seed Item
BTV	Background Threshold Value
CA	Chemical Agent
CAA	Clean Air Act
CAIS	Chemical Agent Identification Set
CAR	Corrective Action Report
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CERCLIS	CERCLA Information System
CFR	Code of Federal Regulations
CG	phosgene
CHE	Chemical Warfare Materiel Hazard Evaluation
CK	cyanogen chloride
CMUA	Concentrated Munitions Use Area
CNWR	Culebra National Wildlife Refuge
COC	Chain of Custody
COD	Certificate of Destruction
COPC	Contaminant of Potential Concern
CR	en peligro critico
CRIM	Center for Collection of Municipal Revenues
CSM	Conceptual Site Model
CRP	Community Relations Plan
CRREL	Cold Regions Research and Engineering Laboratory
CSM	conceptual site model
CWA	Clean Water Act

CWM	Chemical Warfare Materiel
DD	deficiencia de datos
DERP	Defense Environmental Restoration Program
DGM	Digital Geophysical Mapping
DGPS	Differential Global Positioning System
DMM	Discarded Military Munitions
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DON	Department of the Navy
DQO	data quality objective
DVR	Data Validation Report
ECSM	Ecological Conceptual Site Model
EHE	Explosive Hazard Evaluation
EM	Engineer Manual
EMCX	Environmental and Munitions Center of Expertise
EN	en peligro
EOD	explosive ordnance disposal
EPC	Exposure Point Concentration
ER	Engineer Regulation
ERDC	Engineer Research and Development Center
ESE	Environmental Science and Engineering, Inc.
ESL	Ecological Screening Level
ESP	Explosives Siting Plan
ESQD	Explosives Safety Quantity-Distance
ESV	ecological screening value
FAA	Federal Aviation Administration
FDE	Findings and Determination of Eligibility
FE	federally listed as endangered
FLEX	Fleet Landing Exercise
FS	Feasibility Study
FSP	Field Sampling Plan
FT	federally listed as threatened
FUDS	Formerly Used Defense Site
FUDSMIS	Formerly Used Defense Sites Management Information System
FY	Fiscal Year
GIS	geographic information system
GPO	Geophysical Prove-Out

GSV	Geophysical System Verification
HA	Hazard Assessment
HE	high explosive
HFD	Hazardous Fragmentation Distance
HHE	Health Hazard Evaluation
HQ	hazard quotient
HSDB	Hazardous Substances Data Bank
HTW	hazardous and toxic waste
HVAR	High Velocity Aircraft Rocket
IAW	in accordance with
IDW	Investigative Derived Waste
INPR	Inventory Project Report
ISO	Industry Standard Object
IVS	Instrument Verification Strip
LANL	Los Alamos National Laboratory
LDC	Laboratory Data Consultants, Inc.
LUC	Land Use Control
Marines	U.S. Marine Corps
MC	munitions constituent
MD	munitions debris
MDAS	material documented as safe
MEC	munitions and explosives of concern
MFD	Maximum Fragmentation Distance
mg/kg	milligram per kilogram
MGFD	Munition with the Greatest Fragmentation Distance
mm	millimeter
MMRP	Military Munitions Response Program
MPPEH	Material Potentially Presenting an Explosive Hazard
MRS	munition response site
MRSPP	Munitions Response Site Prioritization Protocol
MS	Matrix Spike
MSD	Matrix Spike Duplicate; Military Separation Distance
msl	mean sea level
Navy	U.S. Navy
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ND	Not Detected
NFG	National Functional Guidelines

NHA	National Heritage Area
NHL	National Historic Landmark
NMFS	National Marine Fisheries Service
No.	number
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRIS	National Register Information System
NWP	Northwest Peninsula
OB/OD	Open Burn / Open Detonation
OE	Ordnance and Explosives
OSC	Office of Special Councel
PA	Preliminary assessment
PCOPC	preliminary contaminants of potential concern
PD	Point Detonating
PDA	Personal Digital Assistant
PDT	Project Delivery Team
PEP	Propellant, energetic, and pyrotechnics
PRASA	Puerto Rico Aqueduct and Sewer Authority
PRDNER	Puerto Rico Department of Natural and Environmental Resources
PREQB	Puerto Rico Environmental Quality Board
PRG	preliminary remediation goal
PSV	Preliminary Screening Value
PWS	Performance Work Statement
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
QCSR	Quality Control Summary Report
QSM	Quality System Manual
RA	Risk Assessment
RAB	Restoration Advisory Board
RAC	risk assessment code
RD	Remedial Design
RI	Remedial Investigation
RI/FS	remedial investigation and feasibility study
ROE	right of entry
ROV	Remotely Operated Vehicle
RPM	Remedial Project Manager
RSL	Regional Screening Level

RTI	RTI Laboratories
SAA	Small Arms Ammunition
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act of 1986
SC	species of concern
SERCC	Southeast Regional Climate Center
SHPO	State Historic Preservation Office
SI	site inspection
SLERA	screening level ecological risk assessment
SLRA	screening level risk assessment
SMOA	Superfund Memorandum of Agreement
SOP	Standard Operating Procedure
SSL	soil screening level
SUXOS	Senior Unexploded Ordnance Supervisor
TBC	To Be Considered
TCRA	time-critical removal action
TES	Timberline Environmental Services, Inc.
TESS	Threatened and Endangered Species System
TNT	trinitrotoluene
TPP	technical project planning
TSCA	Toxic Substances Control Act
U.S.	United States
USA	USA Environmental, Inc.
USACE	U.S. Army Corps of Engineers
USAESCH	U.S. Army Corps of Engineers, Engineering and Support Center, Huntsville
USC	U.S. Code
USCB	U.S. Census Bureau
USCG	United States Coast Guard
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTL	Upper Tolerance Level
UXO	unexploded ordnance
UXOQCS	UXO Quality Control Specialist
VOC	Volatile Organic Compound
VSP	Visual Sampling Plan

VU	vulnerable
WQS	Water Quality Standards
WP	Work Plan

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GLOSSARY OF TERMS

- **Administrator** - the Administrator of the United States Environmental Protection Agency. 42 United States Code (USC) 9601
- **Administrative Record –** the documents that form the basis for the selection of a response action compiled and maintained by the lead agency. 40 Code of Federal Regulations (CFR) 800
- **Agent Breakdown Products (ABPs) -** Degradation products of chemical agents; compounds that have been identified that are formed by decomposition, hydrolysis, microbial degradation, oxidation, photolysis, and decontamination. Discussions of ABPs may also include co-contaminants that were impurities formed during manufacture. , Engineer Manual (EM) 200-1-15
- **Anomaly -** Any item that is seen as a subsurface irregularity after geophysical investigation. This irregularity will deviate from the expected subsurface ferrous and non-ferrous material at a site (e.g., pipes, power lines). EM 200-1-15
- **Anomaly Avoidance -** Techniques employed by explosive ordnance disposal or unexploded ordnance (UXO) personnel on property known or suspected to contain UXO, other munitions that may have experienced abnormal environments (e.g., discarded military munitions), munitions constituents in high enough concentrations to pose an explosive hazard, or chemical agent (CA), regardless of configuration to avoid contact with potential surface or subsurface explosive or CA hazards, to allow entry to the area for the performance of required operations. EM 200-1-15
- **ARARs (Applicable or Relevant and Appropriate Requirements) –** 40 CFR 300
    - *Applicable requirements* means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.
    - *Relevant and appropriate requirements* means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

- **Archives Search Report (ASR) -** A detailed investigation to report on past MEC activities conducted on an installation. The principal purpose of the Archives Search is to assemble historical records and available field data, assess potential ordnance presence, and recommend follow-up actions at a Defense Environmental Restoration Program – Formerly Used Defense Sites (DERP-FUDS). There are four general steps in an Archives Search: records search phase, site safety and health plan, site survey, and ASR including risk assessment. EM 200-1-15
- **Barrel** - forty-two United States gallons at sixty degrees Fahrenheit. 42 USC 9601
- **Environmental and Munitions Center of Expertise (EMCX) -** An EMCX is a United States Army Corps of Engineers (USACE) organization that has been approved by Headquarters, USACE as having a unique or exceptional technical capability in a specialized subject area that is critical to other USACE commands. These services may be reimbursable or centrally funded. EM 200-1-15
- **CERCLA** - Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986. 40 CFR 300
- **CERCLIS** (CERCLA Information System) – U. S. Environmental Protection Agency's (USEPA's) comprehensive data base and data management system that inventories and tracks releases addressed or needing to be addressed by the Superfund program. CERCLIS contains the official inventory of CERCLA sites and supports USEPA's site planning and tracking functions. Inclusion of a specific site or area in the CERCLIS data base does not represent a determination of any party's liability, nor does it represent a finding that any response action is necessary. 40 CFR 300
- **Chain of Custody -** The activities and procedures taken throughout the inspection, re-inspection and documentation process to maintain positive control of MPPEH to ensure the veracity of the process used to determine the status of material as to its explosive hazard. This includes all such activities from the time of collection through final disposition. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff For Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **Chemical Warfare Materiel (CWM) -** Items generally configured as a munition containing a chemical compound that is intended to kill, seriously injure, or incapacitate a person through its physiological effects. CWM includes V- and G-series nerve agents or H-series (mustard) and L-series (lewisite) blister agents in other than-munition configurations; and certain industrial chemicals (e.g., hydrogen cyanide [AC, also frequently abbreviated as HCN], cyanogen chloride [CK], or carbonyl dichloride [called phosgene or CG]) configured as a military munition. Due to their hazards, prevalence, and military-unique application, only chemical agent identification sets (CAIS) that contain neat agent or dilute nerve agent are considered CWM. K951/952 are managed as CWM but for storage treatment and disposal are handled as hazardous waste in

accordance with SAIE-ESOH 23 Apr 2007 memo: Treatment of CAIS as Hazardous Waste. CWM does not include: riot control devices; chemical defoliants and herbicides; industrial chemicals (e.g., AC (HCN), CK, CG) not configured as a munition; smoke and other obscuration producing items; flame and incendiary producing items; or soil, water, debris or other media contaminated with low concentrations of chemical agents where no chemical agent hazards exist._Soil, water, debris, or other media contaminated with dispersed V- and G- series nerve agent, H- and HN-series blister agent, or L will be considered and managed in accordance with 40 CFR 266 Subpart M. EM 200-1-15

- **Coastal waters -** the waters of the coastal zone except for the Great Lakes and specified ports and harbors on inland rivers. 40 CFR 300
- **Coastal zone** - all United States waters subject to the tide, United States waters of the Great Lakes, specified ports and harbors on inland rivers, waters of the contiguous zone, other waters of the high seas subject to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and the land surface or land substrata, ground waters, and ambient air proximal to those waters. The term coastal zone delineates an area of federal responsibility for response action. Precise boundaries are determined by USEPA/USCG agreements and identified in federal regional contingency plans. 40 CFR 300
- **Community Relations Plan (CRP) -** Formerly called the Public Involvement Plan, the CRP serves as the framework to establish a successful information exchange with the public during the Environmental Restoration Process. The CRP follows guidelines set forth under the CERCLA of 1980 and the SARA. Each CRP must be tailored to fit the individual site and situation and should also accommodate any site-specific agreements between the U.S. Army and the U.S. Environmental Protection Agency or state environmental agencies. The CRP is not a static document and should be revised to reflect the development and progress of actions at the site. EM 200-1-15
- **Concentrated Munitions Use Area (CMUA) -** munitions response sites (MRSs) or areas within MRSs where there is a high likelihood of finding unexploded ordnance or discarded military munitions and that have a high amount of munitions debris (MD) within them as a result of historical munitions use and fragmentation. CMUAs are most commonly target areas on ranges; however, they also include explosion sites, open burn / open detonation areas, and potentially even disposal sites where munitions have been disposed of over a relatively large area (i.e., not small, isolated burial pits). EM 200-1-15
- **Conceptual Site Model (CSM) -** a description of a site and its environment that is based on existing knowledge. It describes sources and receptors, and the interactions that link these. It assists the team in planning, data interpretation, and communication. EM 200-1-15
- **Construction Support -** Assistance provided by DoD Explosive Ordnance Disposal (EOD) or UXO-qualified personnel and/or by personnel trained and qualified for

operations involving Chemical Agents (CA), regardless of configuration, during intrusive construction activities on property known or suspected to contain UXO, other munitions that may have experienced abnormal environments [e.g., Discarded Military Munitions (DMM)], munitions constituents in high enough concentrations to pose an explosive hazard, or CA, regardless of configuration, to ensure the safety of personnel or resources from any potential explosive or CA hazards. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff For Installation Management, Subject: Munitions Response Terminology, 21 April 2005.

- **Contiguous zone** - the entire zone established or to be established by the United States under article 24 of the Convention of the Territorial Sea and the Contiguous Zone. 42 USC 9601. 33 USC 1362.
- **Conventional Munitions and Explosives of Concern (MEC) -** MEC (see definition) other than chemical warfare materiel, biological warfare materiel, and nuclear ordnance. EM 200-1-15
- **Defense Site -** Locations that are or were owned by, leased to, or otherwise possessed or used by the Department of Defense (DoD). The term does not include any operational range, operating storage or manufacturing facility, or facility that is used for or was permitted for the treatment or disposal of military munitions. 10 U.S.C. 2710(e)(1)
- **Discarded Military Munitions (DMM) -** Military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal. The term does not include unexploded ordnance, military munitions that are being held for future use or planned disposal, or military munitions that have been properly disposed of, consistent with applicable environmental laws and regulations. 10 U.S.C. 2710(e)(2)
- **Discharge** - spilling, leaking, pumping, pouring, emitting, emptying, or dumping, but excludes discharges in compliance with a permit under section 402 of the Clean Water Act (CWA), discharges resulting from circumstances identified and reviewed and made a part of the public record with respect to a permit issued or modified under section 402 of the CWA, and subject to a condition in such permit, or continuous or anticipated intermittent discharges from a point source, identified in a permit or permit application under section 402 of the CWA, that are caused by events occurring within the scope of relevant operating or treatment systems. For purposes of the NCP, discharge also means substantial threat of discharge. 40 CFR 300
- **Disposal** - the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground waters. 42 USC 9601. 42 USC 6903.

- **Disposition -** The process of reusing, recycling, converting, redistributing, transferring, donating, selling, demilitarizing, treating, destroying, or fulfilling other life-cycle guidance, for DoD property. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff For Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **Documentation of the Explosives Safety Status of Material -** Documentation attesting that material: (1) does not present an explosive hazard and is consequently safe for unrestricted transfer within or release from DoD control, or (2) is Matrerial Potentially Presenting an Explosive Hazard (MPPEH), with the known or suspected explosive hazards stated, that is only transferable or releasable to a qualified receiver. This documentation must be signed by a technically qualified individual with direct knowledge of: (a) the results of both the material's 100 percent inspection and 100 percent reinspection or of the approved process used and the appropriate level of reinspection, and (2) the veracity of the chain-of-custody for the material. This signature is followed by the signature of another technically qualified individual who inspects the material on a sampling basis (sampling procedures are determined by DoD entity that is inspecting the material). Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff For Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **Drinking water supply** - any raw or finished water source that is or may be used by a public water system (as defined in the Safe Drinking Water Act [42 U.S.C. 300f et seq.]) or as drinking water by one or more individuals. 42 USC 9601.
- **Environment** - 42 USC 9601.
    - the navigable waters, the waters of the contiguous zone, and the ocean waters of which the natural resources are under the exclusive management authority of the United States under the Magnuson-Stevens Fishery Conservation and Management Act [16 U.S.C. 1801 et seq.], and
    - any other surface water, ground water, drinking water supply, land surface or subsurface strata, or ambient air within the United States or under the jurisdiction of the United States.
- **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. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff for Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **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. EM 200-1-15

- **Explosive Ordnance Disposal (EOD) Personnel -** Military personnel who have graduated from the Naval School, Explosive Ordnance Disposal; are assigned to a military unit with a Service-defined EOD mission; and meet Service and assigned unit requirements to perform EOD duties. EOD personnel have received specialized training to address explosive and certain CA hazards during both peacetime and wartime. EOD personnel are trained and equipped to perform render safe procedures on nuclear, biological, chemical, and conventional munitions, and on improvised explosive devices. EM 200-1-15
- **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. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff for Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **Explosives or Munitions Emergency Response -** All immediate response activities by an explosives and munitions emergency response specialist to control, mitigate, or eliminate the actual or potential threat encountered during an explosives or munitions emergency. An explosives or munitions emergency response may include in-place render-safe procedures, treatment or destruction of the explosives or munitions, and/or transporting those items to another location to be rendered safe, treated, or destroyed. Any reasonable delay in the completion of an explosives or munitions emergency response caused by a necessary, unforeseen, or uncontrollable circumstance will not terminate the explosives or munitions emergency. Explosives and munitions emergency responses can occur on either public or private lands and are not limited to responses at RCRA facilities. 40 CFR 260.10
- **Explosives Safety -** A condition where operational capability and readiness, people, property, and the environment are protected from the unacceptable effects or risks or potential mishaps involving military munitions. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff for Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **Feasibility Study (FS)** - a study undertaken by the lead agency to develop and evaluate options for remedial action. The RI data are used to define the objectives of the response action, to develop remedial action alternatives, and to undertake an initial screening and detailed analysis of the alternatives. The term also refers to a report that describes the results of the study. 40 CFR 300
- **Former Range** - the munitions response site is a location that was:

(1) Closed by a formal decision made by the DoD Component with administrative control over the location, or

(2) Put to a use incompatible with the presence of UXO, DMM, or munitions constituents (MC). 32 CFR 179

- **Formerly Used Defense Sites (FUDS) –** facility or site which was under the jurisdiction of the Secretary of Defense and owned by, leased to, or otherwise possessed by the United States at the time of actions leading to contamination by hazardous substances, for which the Secretary of Defense shall carry out all response actions with respect to releases of hazardous substance from that facility or site. 10 USC 2701
- **Geophysical Techniques -** Techniques utilized for the detection and measurement of buried anomalies (e.g., ferromagnetic indicators and ground penetrating radar) to investigate the presence of munitions. EM 200-1-15
- **Ground water** - water in a saturated zone or stratum beneath the surface of land or water. 42 USC 9601
- **Hazardous Fragmentation Distance (HFD) -** Distance at which the areal number density of hazardous fragments or debris becomes one per 600 square feet (55.7 square meters). EM 200-1-15
- **Hazardous substance** - 42 USC 9601
    - any substance designated pursuant to section 311(b)(2)(A) of the Federal Water Pollution Control Act [33 U.S.C. 1321 (b)(2)(A)],
    - any element, compound, mixture, solution, or substance designated pursuant to section 9602 of CERCLA,
    - any hazardous waste having the characteristics identified under or listed pursuant to section 3001 of the Solid Waste Disposal Act [42 U.S.C. 6921] (but not including any waste the regulation of which under the Solid Waste Disposal Act [42 U.S.C. 6901 et seq.] has been suspended by Act of Congress),
    - any toxic pollutant listed under section 307(a) of the Federal Water Pollution Control Act [33 U.S.C. 1317 (a)],
    - any hazardous air pollutant listed under section 112 of the Clean Air Act (CAA) [42 U.S.C. 7412], and
    - any imminently hazardous chemical substance or mixture with respect to which the Administrator has taken action pursuant to section 7 of the Toxic Substances Control Act (TSCA) [15 U.S.C. 2606].
    - The term does not include petroleum, including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance under subparagraphs (A) through (F) of this paragraph, and the term does not include natural gas, natural gas liquids, liquefied natural gas, or synthetic gas usable for fuel (or mixtures of natural gas and such synthetic gas).
- **Hazardous waste** - a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may—

  - cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or
  - pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed. 42 USC 9601. 42 USC 6903.

- **Historical Evidence** - the investigation:

(1) Found written documents or records, or
(2) Documented interviews of persons with knowledge of site conditions, or
(3) Found and verified other forms of information. 32 CFR 179

- **Intrusive Activity -** Activity that involves or results in the penetration of the ground surface at an area known or suspected to contain munitions and explosives of concern. Intrusive activities can be of an investigative or removal action nature. EM 200-1-15
- **Land Use Controls (LUCs) -** physical, legal, or administrative mechanisms that restrict the use of, or limit access to, real property, to prevent or reduce risks to human health and the environment. Physical Mechanisms encompass a variety of engineered remedies to contain or reduce contamination and physical barriers to limit access to real property, such as fences or signs. The legal mechanisms used for LUCs are generally the same as those used for institutional controls as discussed in the NCP. DODM 4715.20
- **Lead Agency** - the agency that provides the Office of Special Counsel (OSC)/Remedial Project Manager (RPM) to plan and implement response actions under the NCP. USEPA, the USCG, another federal agency, or a state (or political subdivision of a state) operating pursuant to a contract or cooperative agreement executed pursuant to section 104(d)(1) of CERCLA, or designated pursuant to a Superfund Memorandum of Agreement (SMOA) entered into pursuant to subpart F of the NCP or other agreements may be the lead agency for a response action. In the case of a release of a hazardous substance, pollutant, or contaminant, where the release is on, or the sole source of the release is from, any facility or vessel under the jurisdiction, custody, or control of DOD or Department of Energy (DOE), then DOD or DOE will be the lead agency. Where the release is on, or the sole source of the release is from, any facility or vessel under the jurisdiction, custody, or control of a federal agency other than USEPA, the USCG, DOD, or DOE, then that agency will be the lead agency for remedial actions and removal actions other than emergencies. The federal agency maintains its lead agency responsibilities whether the remedy is selected by the federal agency for non-NPL sites or by USEPA and the federal agency or by USEPA alone under CERCLA section 120. 40 CFR 300
- **Mag & Flag -** The use of geophysical equipment to survey an area in a real-time mode and mark the location of geophysical anomalies. This method is performed without using post data processing. EM 200-1-15
- **Material Potentially Presenting an Explosive Hazard (MPPEH) -** Material owned or controlled by the DoD that, prior to determination of its explosives safety status, potentially contains explosives or munitions (e.g., munitions containers and packaging

material; MD remaining after munitions use, demilitarization, or disposal; and range-related debris) or potentially contains a high enough concentration of explosives that the material presents an explosive hazard (e.g., equipment, drainage systems, holding tanks, piping, or ventilation ducts that were associated with munitions. EM 200-1-15

- **Maximum Fragmentation Distance (MFD) -** The calculated maximum distance to which any fragment from the cylindrical portion of an ammunition and explosives (AE) case is expected to be thrown by the design mode detonation of a single AE item. This distance does not address fragments produced by sections of nose plugs, base plates, boat tails, or lugs. These special fragments, from the non-cylindrical portions of the AE case, can travel to significantly greater distances (i.e., more than 10,000 feet [3,048 meters]) than the calculated maximum distances. The maximum fragment distance also may be the measured distance, based on testing, to which any fragment from an AE item is thrown. EM 200-1-15
- **Military Munitions -** all ammunition products and components produced 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 DOE, 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 DOE after all required sanitization operations under the Atomic Energy Act (AEA) of 1954 (42 U.S.C. ,2011 et seq.) have been completed. 10 U.S.C. 2710(e)(4)
- **Military Range -** Designated land and water areas set aside, managed, and used to conduct research on, develop, test, and evaluate military munitions and explosives, other ordnance, or weapon systems, or to train military personnel in their use and handling. Ranges include firing lines and positions, maneuver areas, firing lanes, test pads, detonation pads, impact areas, and buffer zones with restricted access and exclusionary areas. 40 CFR 260.10
- **Military Separation Distance (MSD) -** the distance at which personnel in the open must be from an intentional or unintentional detonation. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff for Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **Munition Response Site (MRS) -** A discrete location within a MRA that is known to require a munitions response. EM 200-1-15

- **Munition with the Greatest Fragmentation Distance (MGFD) -** The munition with the greatest fragment distance that is reasonably expected (based on research or characterization) to be encountered in any particular area. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff For Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **Munitions and Explosives of Concern (MEC) -** specific categories of military munitions that may pose unique explosives safety risks, specifically composed of (a) UXO, (b) DMM, or (c) MC (e.g., TNT, RDX) present in high enough concentrations to pose an explosive hazard. EM 200-1-15
- **Munitions Constituents (MC) -** Any materials originating from UXO, DMM, or other military munitions, including explosive and non-explosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions. 10 U.S.C. 2710(e)(3)
- **Munitions Debris (MD) -** Remnants of munitions (e.g., fragments, penetrators, projectiles, shell casings, links, fins) remaining after munitions use, demilitarization, or disposal. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff For Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **Munitions Response -** Response actions, including investigation, removal actions and remedial actions to address the explosives safety, human health, or environmental risks presented by unexploded ordnance, discarded military munitions, or munitions constituents. EM 200-1-15
- **National Oil and Hazardous Substances Pollution Contingency Plan (NCP)** – The plan revised pursuant to 42 USC 9605 and found at 40 CFR 300 that sets out the plan for hazardous substance remediation under CERCLA. 40 CFR 300
- **Natural resources** - land, fish, wildlife, biota, air, water, ground water, drinking water supplies, and other such resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the United States (including the resources of the fishery conservation zone established by the Magnuson-Stevens Fishery Conservation and Management Act [16 U.S.C. 1801 et seq.]), any State or local government, any foreign government, any Indian tribe, or, if such resources are subject to a trust restriction on alienation, any member of an Indian tribe. 42 USC 9601
- **On-site** - the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action. 40 CFR 300
- **On-the-Surface -** A situation in which UXO, DMM or CA, regardless of configuration, are:
    (1) Entirely or partially exposed above the ground surface (i.e., the top of the soil layer); or
    (2) Entirely or partially exposed above the surface of a water body (e.g., because of tidal activity). Department of the Army Office of the Assistant Secretary

Installations and Environment, Memorandum for the Assistant Chief of Staff For Installation Management, Subject: Munitions Response Terminology, 21 April 2005.

- **Open Detonation (OD) -** An open-air process used for the treatment of excess, unserviceable or obsolete munitions whereby an explosive donor charge initiates the munitions being treated. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff For Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **Ordnance and Explosives (OE)** - Anything related to munitions designed to cause damage to personnel or material through explosive force, incendiary action or toxic effects. OE is: bombs and warheads, missiles; artillery, mortar and rocket ammunition, small arms ammunition; antipersonnel and antitank mines; demolition charges; high explosives and propellants; depleted uranium rounds; military chemical warfare materials, and all similar and related items or components, explosive in nature or otherwise designed to cause damage to personnel or material (e.g., fuze, boosters/propellants or soils/media contaminated with explosives if the concentration is sufficient to be reactive.) ER 385-1-92
- Other Debris - Debris found on operational ranges or munitions response sites, 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. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff For Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **Person** - an individual, firm, corporation, association, partnership, consortium, joint venture, commercial entity, United States Government, State, municipality, commission, political subdivision of a State, or any interstate body. 42 USC 9601
- **Physical Evidence** – (1) Recorded observations from on-site investigations, such as finding intact UXO or DMM, or components, fragments, or other pieces of military munitions, or (2) The results of field or laboratory sampling and analysis procedures, or (3) The results of geophysical investigations. 32 CFR Part 179
- **Pollutant or contaminant** - any element, substance, compound, or mixture, including disease-causing agents, which after release into the environment and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will or may reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions (including malfunctions in reproduction) or physical deformations, in such organisms or their offspring; except that the term "pollutant or contaminant" shall not include petroleum, including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance under

subparagraphs (A) through (F) of paragraph (14) and shall not include natural gas, liquefied natural gas, or synthetic gas of pipeline quality (or mixtures of natural gas and such synthetic gas). 42 USC 9601

- **Preliminary assessment (PA)** - review of existing information and an on or off-site reconnaissance, if appropriate, to determine if a release may require additional investigation or action. 40 CFR 300
- **Primary Explosives -** highly sensitive compounds that are typically used in detonators and primers. A reaction is easily triggered by heat, spark, impact or friction. Examples of primary explosives are lead azide and mercury fulminate. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff for Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **Quality Assurance Project Plan (QAPP)** - a written document, associated with all remedial site sampling activities, which presents in specific terms the organization (where applicable), objectives, functional activities, and specific quality assurance (QA) and quality control (QC) activities designed to achieve the data quality objectives of a specific project(s) or continuing operation(s). The QAPP is prepared for each specific project or continuing operation (or group of similar projects or continuing operations). The QAPP will be prepared by the responsible program office, regional office, laboratory, contractor, recipient of an assistance agreement, or other organization. For an enforcement action, potentially responsible parties may prepare a QAPP subject to lead agency approval. 40 CFR 300
- **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 (FAA). 10 U.S.C. 2710(e)(1)
- **Range Activities -** Research, development, testing, and evaluation of military munitions, other ordnance, and weapons systems; and the training of members of the armed forces in the use and handling of military munitions, other ordnance, and weapons systems. 10 U.S.C. 2710(e)(2)
- **Range Clearance -** The destruction, or removal and proper disposition of used military munitions (e.g., unexploded ordnance (UXO) and MD) and other range-related debris (e.g., target debris, military munitions packaging and crating material) to maintain or enhance operational range safety or prevent the accumulation of such material from impairing or preventing operational range use. “Range clearance” does not include removal, treatment, or remediation of chemical residues or munitions constituents from environmental media, nor actions to address discarded military munitions (e.g., burial pits) on operational ranges. Department of the Army Office of the Assistant Secretary

Installations and Environment, Memorandum for the Assistant Chief of Staff For Installation Management, Subject: Definition Related to Munitions Response Action, 28 October 2003

- **Range Related Debris -** Debris, other than MD, collected from operational ranges or from former ranges (e.g., target debris, military munitions packaging and crating material). Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff For Installation Management, Subject: Definition Related to Munitions Response Action, 28 October 2003
- **Remedial Design (RD)** - the technical analysis and procedures which follow the selection of remedy for a site and result in a detailed set of plans and specifications for implementation of the remedial action. 40 CFR 300
- **Remedial Investigation (RI)** - a process undertaken by the lead agency to determine the nature and extent of the problem presented by the release. The RI emphasizes data collection and site characterization, and is generally performed concurrently and in an interactive fashion with the feasibility study. The RI includes sampling and monitoring, as necessary, and includes the gathering of sufficient information to determine the necessity for remedial action and to support the evaluation of remedial alternatives. 40 CFR 300
- **Remedial Project Manager (RPM)** - the official designated by the lead agency to coordinate, monitor, or direct remedial or other response actions under subpart E of the NCP. 40 CFR 300
- **Remedy** [or **remedial action**] - those actions consistent with permanent remedy taken instead of or in addition to removal actions in the event of a release or threatened release of a hazardous substance into the environment, to prevent or minimize the release of hazardous substances so that they do not migrate to cause substantial danger to present or future public health or welfare or the environment. The term includes, but is not limited to, such actions at the location of the release as storage, confinement, perimeter protection using dikes, trenches, or ditches, clay cover, neutralization, cleanup of released hazardous substances and associated contaminated materials, recycling or reuse, diversion, destruction, segregation of reactive wastes, dredging or excavations, repair or replacement of leaking containers, collection of leachate and runoff, onsite treatment or incineration, provision of alternative water supplies, and any monitoring reasonably required to assure that such actions protect the public health and welfare and the environment. 42 USC 9601
- **Remove** [or **removal**] - the cleanup or removal of released hazardous substances from the environment, such actions as may be necessary taken in the event of the threat of release of hazardous substances into the environment, such actions as may be necessary to monitor, assess, and evaluate the release or threat of release of hazardous substances, the disposal of removed material, or the taking of such other actions as may be necessary

to prevent, minimize, or mitigate damage to the public health or welfare or to the environment, which may otherwise result from a release or threat of release. The term includes, in addition, without being limited to, security fencing or other measures to limit access, provision of alternative water supplies, temporary evacuation and housing of threatened individuals not otherwise provided for, action taken under section 9604 (b) of this title, and any emergency assistance which may be provided under the Disaster Relief and Emergency Assistance Act [42 U.S.C. 5121 et seq.]. 42 USC 9601.

- **Respond** [or **response**] - remove, removal, remedy, and remedial action; all such terms (including the terms "removal" and "remedial action") including enforcement activities related thereto. 42 USC 9601.
- **Restoration Advisory Board (RAB) -** forum for the discussion and exchange of information between representatives of the DoD, regulators, state and local governments, tribal governments, and the affected community. RABs provide an opportunity for stakeholders to have a voice and actively participate in the review of technical documents, to review restoration progress, and to provide individual advice to decision makers regarding restoration activities at DERA-funded Projects. EM 200-1-15
- **SARA (Superfund Amendments and Reauthorization Act of 1986)** - In addition to certain free-standing provisions of law, it includes amendments to CERCLA, the Solid Waste Disposal Act, and the Internal Revenue Code. Among the free-standing provisions of law is Title III of SARA, also known as the "Emergency Planning and Community Right-to-Know Act of 1986" and Title IV of SARA, also known as the "Radon Gas and Indoor Air Quality Research Act of 1986." Title V of SARA amending the Internal Revenue Code is also known as the "Superfund Revenue Act of 1986." 40 CFR 300
- **Secondary Explosives -** explosives that are generally less sensitive to initiation than primary explosives and are typically used in booster and main charge applications. A severe shock is usually required to trigger a reaction. Examples are TNT, cyclo- 1,3,5-trimethylene-2,4,6-trinitramine (RDX or cyclonite), HMX, and tetryl. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff for Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **Security interest** — right under a mortgage, deed of trust, assignment, judgment lien, pledge, security agreement, factoring agreement, or lease and any other right accruing to a person to secure the repayment of money, the performance of a duty, or any other obligation by a nonaffiliated person. 42 USC 9601.
- **Site inspection (SI)** - an on-site investigation to determine whether there is a release or potential release and the nature of the associated threats. The purpose is to augment the data collected in the preliminary assessment and to generate, if necessary, sampling and other field data to determine if further action or investigation is appropriate. 40 CFR 300
- **Small Arms Ammunition** - Ammunition, without projectiles that contain explosives (other than tracers) that is .50 caliber or smaller, or for shotguns. 32 CFR 179

- **Technology-aided Surface Removal -** A removal of UXO, DMM or CWM on the surface (i.e., the top of the soil layer) only, in which the detection process is primarily performed visually, but is augmented by technology aids (e.g., hand-held magnetometers or metal detectors) because vegetation, the weathering of UXO, DMM or CWM, or other factors make visual detection difficult. Department of the Army Office of the Assistant Secretary Installations and Environment, Memorandum for the Assistant Chief of Staff for Installation Management, Subject: Munitions Response Terminology, 21 April 2005.
- **Time Critical Removal Action (TCRA) -** Removal actions where, based on the site evaluation, a determination is made that a removal is appropriate, and that less than 6 months exists before on-site removal activity must begin. 40 CFR 300
- **Transport** or **Transportation** - the movement of a hazardous substance by any mode, and in the case of a hazardous substance which has been accepted for transportation by a common or contract carrier, the term "transport" or "transportation" shall include any stoppage in transit which is temporary, incidental to the transportation movement, and at the ordinary operating convenience of a common or contract carrier, and any such stoppage shall be considered as a continuity of movement and not as the storage of a hazardous substance. 42 USC 9601
- **State** - the several States of the United States, the District of Columbia, the Commonwealth of Puerto Rico, Guam, American Samoa, the United States Virgin Islands, the Commonwealth of the Northern Marianas, and any other territory or possession over which the United States has jurisdiction. 42 USC 9601
- **Unexploded Ordnance (UXO) -** Military munitions that:
  (1) Have been primed, fuzed, armed, or otherwise prepared for actions;
  (2) Have been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material; and
  (3) Remain unexploded whether by malfunction, design, or any other cause. 10 U.S.C. 101(e)(5)
- **United States** - the several states of the United States, the District of Columbia, the Commonwealth of Puerto Rico, Guam, American Samoa, the United States Virgin Islands, the Commonwealth of the Northern Marianas, and any other territory or possession over which the United States has jurisdiction. 40 CFR 300
- **UXO Technicians -** Personnel who are qualified for and filling Department of Labor, Service Contract Act, Directory of Occupations, and contractor positions of UXO Technician I, UXO Technician II, and UXO Technician III. EM 200-1-15
- **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. EM 200-1-15

- **Vessel** - watercraft or other artificial contrivance used, or capable of being used, as a means of transportation on water. 42 USC 9601

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CHAPTER 1. EXECUTIVE SUMMARY

A Remedial Investigation (RI) is not a removal action; rather it is used to determine the nature and extent of the munitions-related contamination in order to develop recommendations for the next action to be taken, if any. The RI and the associated Feasibility Study (FS) Reports for the Culebra Island Munition Response Sites (MRSs) have been prepared as separate volumes consisting of two reports – the RI Report and the FS Report. The two reports address the terrestrial areas in six of the 14 identified MRSs associated with Culebra Island. Significant known details of the water portions of Culebra Island are presented to support the terrestrial investigation when applicable. However, the water portions will be evaluated in a separate report. The six MRSs evaluated in this RI on Culebra Island include MRS 06, MRS 08, MRS 09, MRS 10, MRS 11, and MRS 13. The other MRSs are addressed under separate contracts. The conclusions and recommendations of this report apply only to the terrestrial portions of the six MRSs addressed in the RI.

1.1 BACKGROUND

In 1898, the Spanish American War concluded and the Kingdom of Spain ceded all of Puerto Rico to include Culebra and its adjacent cays to the U.S. Shortly after, in 1900, President Theodore Roosevelt placed Culebra under the jurisdiction of the Department of the Navy (DON). In 1903, the Navy acquired approximately 4,200 acres of land by transfer and purchase; further donations, transfers, and leases between 1939 and 1965 brought the total land acquired to approximately 4,800 acres. Although portions of the site were never formally acquired, military use included the entire Island of Culebra and all surrounding cays. The Navy retained 87.5 acres near Flamenco Point that are not eligible for the Formerly Used Defense Site (FUDS) program. The Northwest Peninsula (NWP) Target Area was also deemed ineligible for the FUDS program per Public Law 93-166 (Military Construction Authorization Act, 1974). The 2005 revised Findings and Determination of Eligibility (FDE) report states that the site, except for 87.5 acres recently transferred from the control of the Navy and the 408 acres of the NWP (1982 Quit Claim Deed), has been determined to be formerly used by the Department of Defense (DoD) [U.S. Army Corps of Engineers (USACE), 2005]. All military use of the island was terminated in 1975. In summary, the Island of Culebra, nearby cays, and surrounding water were used between 1902 and 1975 for training and live fire of bombs, mortars, rockets, torpedoes, projectiles, and small arms. Figure 1-1 shows the location of Culebra and the MRSs addressed in this contract. The MRS Site Map, Figure 1-2, shows more detail on the MRSs and provides land and water acreages. Appendix A, Figure A1, comprised of Plate 2 of the Archives Search Report (ASR) shows areas of historical DoD activity.

During the Site Inspection (SI) completed by Parsons in 2007, the Culebra Island MRS was evaluated for Munitions and Explosives of Concern (MEC) and Munitions Constituents (MC). The MRSs included in the SI were established in the Revised Inventory Project Report (INPR) that was completed in June 2005 (USACE, 2005). The 2005 Revised INPR further defined the military use of the Island of Culebra and divided the original site, Property No I02PR0068, into 14 separate projects, one Hazardous and Toxic Waste (HTW) project and 13 MRSs. The SI recommended conducting an RI/FS for the 13 MRSs. Six MRSs were included for further evaluation under Contract W912DY-04-D-0006, Task Order 0022 and are listed below (the remaining MRSs have been included in separate RI efforts):

- Artillery Firing Area (MRS 06) – Project No. I02PR006806
- Cayo Norte Impact Area (MRS 08) – Project No. I02PR006808
- Soldado Point Mortar and Bombing Area (MRS 09) – Project No. I02PR006809
- Defensive Firing Area No. 1 (MRS 10) – Project No. I02PR006810
- Defensive Firing Area No. 2 (MRS 11) – Project No. I02PR006811
- Cayo Luis Peña Impact Area (MRS 13) – Project No. I02PR006813

Note: An INPR revision prepared in 2017 following RI fieldwork separated MRS 09 and MRS 13 by land and water areas, with the land areas retaining the original MRS number and project numbers. This RI Report addresses the land areas. The water areas are addressed in a separate RI Report. MRS 09 was divided into two MRSs: MRS 09 - Soldado Point Land Area (Project No. I02PR006809) and MRS 19 - Soldado Point Water Area (Project No. I02PR006819). MRS 13 was divided into one land area, MRS 13 - Cayo Luis Peña Land Area (Project No. I02PR006813); and two water areas based on explosive hazard present: MRS 17 - Cayo Luis Peña North Water Area (Project No. I02PR006817) and MRS 18 - Cayo Luis Peña South Water Area (Project No. I02PR006818).

This RI Report uses the acreages updated in the INPR revision for MRS 09 and MRS 13 (acreages will differ from acreages published in the Formerly Used Defense Sites Management Information System Database [FUDSMIS]. Since the 2017 INPR had not been finalized at the time of publication of the RI Report, the original MRS names for MRS 09 and MRS 13 are retained.

This RI Report addresses the characterization of the former Culebra Island MRSs to support the determination of whether there is an unacceptable hazard at each MRS. Where an unacceptable hazard is defined, a FS will be conducted for the purpose of developing and evaluating effective remedial alternatives at each MRS.

The Culebra Island MRSs included in this RI are shown in Figure 1-2. Descriptions for Culebra Island MRSs included in this RI are presented below. Further details regarding spatial relationships among MRSs, historical range activity, and findings of the MEC investigation are found on Figures A-31 through A-36.

As part of the Technical Project Planning (TPP) process, the TPP Team developed a Conceptual Site Model (CSM) for each of the six Culebra Island MRSs addressed under this contract. The preliminary CSMs were developed in support of the TPP process and are presented in Chapter 3. A CSM is a dynamic document that is to be evaluated and revised each time new information is received. Since an SI was completed for this site, the preliminary CSMs for this RI were based on the SI findings (Parsons, 2007). The CSMs were revised based on the RI findings and are presented in Chapter 5.

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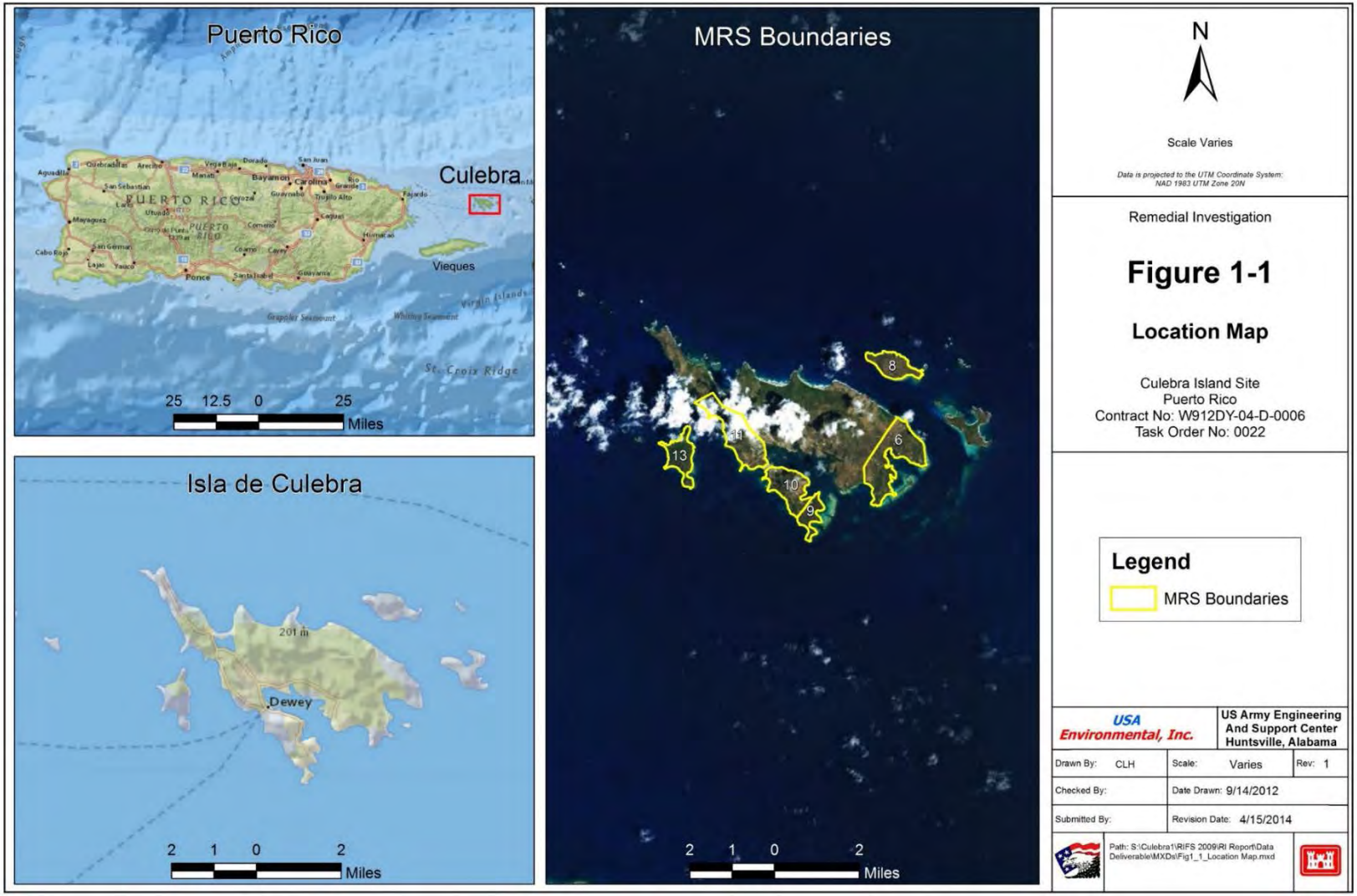

Figure 1-1: Location Map

Figure 1-2: Culebra Island MRS Map

1.2 REMEDIAL INVESTIGATION

The initial Culebra Island RI field work was conducted between May and October 2011. In 2013, a groundwater investigation involving a well survey and groundwater sampling was added to the project. Field work for the groundwater investigation was conducted in September and December 2013. The RI included the following field investigation activities:

- Digital Geophysical Mapping (DGM) (Transects and Grids)
- Anomaly Reacquisition and Intrusive Investigation (Grids)
- Analog Mag-and-Dig Investigations (Beach areas and accessible trails)
- Underwater visual transects using a Remotely Operated Vehicle (ROV)
- Demolition and Disposal

Table 1-1 summarizes the planned and completed MEC investigation. The MEC investigation was conducted by DGM transects and grids and analog transects in each MRS. Table 1-2 summarizes the anomaly investigation results for the RI. Table 1-3 provides the environmental sampling summary for the RI.

Table 1-1: Planned and Completed Geophysical Survey Coverage

MRS	MRS Acres (Land Acres Only)	Planned/ Completed DGM Transect Acres	Planned/ Completed Grid Acres	Planned/ Completed Analog Transect Acres	Planned/ Completed Geophysical Acres	Percentage of Land Acres Investigated
6	826	3.02 / 3.44	1.0 / 0.97	1.05 / 1.05	5.07 / 5.46	0.61 / 0.66%
8	306	1.44 / 1.52	0.5 / 0.52	0.35 / 0.36	2.29 / 2.4	0.75 / 0.78%
9	203/197.4	1.08 / 1.75	0.98 / 0.98	0.15 / 0.15	2.21 / 2.88	1.09 / 1.46%
10	522	4.18 / 4.81	0.98 / 0.89	0.29 / 0.29	5.45 / 5.99	1.04 / 1.15%
11	694.3	4.55 / 5.12	0.98 / 0.97	1.06 / 1.06	6.59 / 7.15	0.95 / 1.03%
13	484/334.2	0	0	2.0 / 3.33	2.0 / 3.33	0.41 / 1.0%

Note: The acreages used in planning were not changed to reflect the 2017 INPR acreage changes. The second number in each box reflects the results from using 2017 INPR revised acreage and numbers for completed work.

Table 1-2: Summary of RI Intrusive Investigation Results

Investigation Type/MRS	Number of Locations						
	MEC	MD[Note 1]	SAA	Other Debris	Hot Rock	Seed Items	Total
DGM Anomalies							
MRS 06	0	4	0	74	310	17	405
MRS 08	0	12	0	1	201	8	222
MRS 09	0	8	0	21	205	14	248
MRS 10	0	0	0	30	161	14	205
MRS 11	0	15	0	44	104	15	178
MRS 13	-	-	-	-	-	-	-
Analog Anomalies							
MRS 06	0	0	0	44	0	14	58
MRS 08	0	0	0	26	0	1	27
MRS09	2[(3)]	0	0	20	0	4	26
MRS 10	0	0	0	35	0	6	41
MRS 11	0	2	0	38	0	24	64
MRS 13	0	10	2	304	72	20	408
Total	**2**	**51**	**2**	**637**	**1,054**	**137**	**1,882**

SAA-Small Arms Ammunition

Note 1: Types of MD and locations where found in each MRS are identified on Figures A-31 to A-36. Munition type for some items was not fully identifiable. MD observations from a 2009 post award Site Visit were also used in the MEC assessment, but are not included here.

Note 2: Underwater investigations identified items of interest that could have been possible MEC/MD in MRS 11 and MRS 13. These underwater items have not been confirmed as MEC/MD and therefore have not been added to this table but are discussed within the body of the report.

Note 3: Two MK 25 Marine Markers were discovered in MRS 09 following further evaluation indicated the Marine Markers were expended and not likely MEC. However, the shape of the items inhibited full evaluation, and therefore the items were destroyed by detonation. Marine Markers are used in both civilian and military marine activity and it is not certain the items were related to DoD site use.

Table 1-3: RI MC Sample Locations and Rationale

MRS	Media	Number	QC	Rationale
06	Soil (Surface)	4	1	Collected in a location where MEC or MD were discovered and/or destroyed
	Groundwater	2	1	Collected from existing wells in the general vicinity of MD findings or historical DoD activity.
08	Soil (Surface)	12	2	Collected in a location where MEC or MD were discovered and/or destroyed
09	Soil (Surface) Surface Water Sediment Groundwater	8 3 3 1	2 1 1 0	Collected in a location where MEC/MD were discovered and/or destroyed. Sediment and Surface Water in down gradient areas from MEC/MD finds. Collected from a well installed as part of the RI in the general vicinity of where MD was discovered.
10	Soil (Surface)	0	0	No MEC or MD were discovered or destroyed in this MRS and therefore, IAW the Work Plan (WP), no samples were collected.
11	Soil (Surface)	28	2	Collected in a location where MEC or MD were discovered and/or destroyed.
	Groundwater	1	0	Collected from a well installed as part of the RI in the general vicinity of MD findings.
13	Soil (Surface)	32	3	Collected in a location where MEC or MD were discovered and/or destroyed.
Total		94	13	

1.3 MEC

The potential for human and ecological exposure to MEC was evaluated at each of the six Culebra Island MRSs as part of this RI. Chapter 4 provides details for MEC Characterization and Chapter 7 provides the details of the Baseline Risk Assessment for MEC. The following paragraphs and Table 1-4 summarize the MEC characterization results of the RI for each MRS.

1.3.1 MRS 06 - Artillery Firing Area

MRS 06 had both DGM and Analog transects located throughout the site. DGM grids were also placed within MRS 06 in areas identified by the Project Delivery Team (PDT). Right of Entry (ROE) could not be obtained or was denied in a significant portion of MRS 06, which required the revision of transect placement. In these areas, grids and/or transects were located as close to the original planned locations (based on terrain and available ROE) as possible so as to adequately characterize the area and meet the required acreage identified within the USACE approved WP. Table 1-1 presents the planned and completed acreages for transects and grids within MRS 06. Historical ranges shown in relation to the RI MEC investigation for MRS 06, along with areas where ROEs could not be obtained or were refused, are shown on Appendix A: Figure A-31.

Anomalies identified by DGM and analog methods were intrusively investigated within the grids. No munitions debris (MD) or MEC items were found within MRS 06 during the analog investigations. During the DGM intrusive investigation, four MD items were located and these were identified as two expended artillery primers (specific type unidentifiable), one piece of unidentified fragmentation, and one unidentified MD item.

No target remnants, physical evidence, or high-density anomaly areas indicating a target area or Concentrated Munitions Use Area (CMUA) were discovered in MRS 06. Four MD items were discovered. Two of the MD items, a munition fragment and what the field team believed was a fragment from a rotating band, were discovered at significant distances from each other (Grid 6-3 and Grid 6-17). The two additional MD items were expended artillery primers found in Grid 6-7. A post-Visual Sampling Plan (VSP) anaylsis was conducted on the RI data and was used to determine if any significant data gaps in MRS 06 exist that might need further characterization. The VSP analysis requires a munition type as part the input data. During the RI, no specific munitions types were identifiable from the four MD items found. Thus, munitions suspected to have impacted neighboring MRSs (4.2 inch mortar and 75mm projectile) were used as the input parameters in the VSP analysis. The VSP Post-analysis results determined there were no RI data gaps for MRS 06. There have been no reports of MEC discoveries or disposal by authorities or explosive ordnance disposal (EOD) Teams for MRS 06. There is no evidence human receptors are exposed to an unacceptable MEC hazard within MRS 06.

The fragmentation items are likely the result of munitions detonating in target areas outside of MRS 06 and the fragments landing within the MRS 06 boundary and therefore are considered anomalous to this MRS. The low density of the recovered MD in MRS 06 is not indicative of these areas being used as target or impact areas. Firing point locations have been historically documented and there is no historical evidence of MEC discoveries in MRS 06. Therefore, the potential for human receptors to encounter surface or subsurface MEC at MRS 06 is considered negligible.

In addition to the DGM and Analog investigations, the field teams completed 4.36 acres of underwater visual transects exceeding the planned acreage of 4.11 transect acres. The underwater visual transects did not find any evidence of target areas or high munitions use areas (MEC, MD, target remnants, etc.). No historical evidence of surface floating or underwater targets for MRS 06 was found.

Due to the size and geography of the MRS (i.e., Mangrove Bay partially bisects the MRS), it was determined that the receptor populations in the northern and southern portions of the MRS are

likely different. Therefore, a separate evaluation of the northern and southern portions of the MRS was conducted to provide a more accurate representation of the hazards to human and ecological receptors at this site. Thus, for assessment purposes only, the evaluation of the MRS has been presented separately for MRS 06 North and MRS 06 South. MRS 06 is one MRS and there is no intention to administratively separate MRS 06 into two separate MRSs (MRS 06 North or MRS 06 South).

MRS 06 is almost entirely privately owned. However, the Commonwealth of Puerto Rico Department of Natural and Environmental Resources (PRDNER) has jurisdiction over a 1,000 meter wide belt of all Puerto Rico's coastal lands (and additional distances where needed to protect key coastal natural systems), and the territorial waters, including submerged lands beneath them, extending 9 nautical miles offshore. The U.S. Fish and Wildlife Service (USFWS) is co-manager of the coastal zone as part of the Culebra National Wildlife Refuge (CNWR). Receptors include residents, recreational users, construction workers, and site visitors. The MRS contains several residences scattered throughout the MRS. Portions of the MRS are currently being developed. Increased development in the MRS is likely. Future receptors would likely be the same, with an increase in numbers present. Access is unrestricted throughout the MRS. Sensitive ecological receptors are present.

The two expended artillery primers found in Grid 6-7 are believed to have originated from inside MRS 06 but there was no other discoveries in Grid 6-7 to indicate a firing point such as; a burial pit, Discarded Military Munitions (DMM) or other indications of a firing point requiring additional investigation or removal action. The two munition fragments found in MRS 06 were likely from a target outside the MRS and considered anomalous to this MRS, there is no significant source of MEC hazard. Based on historical documents there have been no past discoveries of MEC and the RI field work found no evidence to support that a MEC hazard exists at the MRS, however, as with all of Culebra, it is possible that MEC may exist in MRS 06 due to its use as a firing point but the hazard is considered low. MRS 06 is recommended to proceed to an FS to address the negligible MEC hazard.

1.3.2 MRS 08 Cayo Norte Impact Area

There are sufficient amounts of MD to confirm the western side of MRS 08 was used as 75 mm artillery target area (from MRS 06 firing points), even if for a short period of time. No MEC or MD items were recovered along the beach areas of MRS 08. Historical ranges shown in relation to the RI MEC investigation for MRS 08 are shown in Appendix A: Figure A-32.

In accordance with the WP, field teams completed 3.31 acres of underwater visual transects, exceeding the planned acreage of 2.32 transect acres. The underwater visual transects did not find evidence of target areas or high munitions use areas (MEC, MD, target remnants, etc.). No historical evidence of surface floating or underwater targets for MRS 08 was found.

MRS 08 covers all of Cayo Norte, a privately owned island with unrestricted public access. However, to reach the MRS requires a boat; in addition, vegetation and steep and rugged terrain provide a natural barrier. Potential receptors include residents, construction workers, on-site workers, recreational users, and trespassers. This combination of needing a boat and the nature of the island's land features serves to limit access to portions of the MRS. Sensitive ecological receptors are present.

The presence of MD in the upland areas indicates the possibility for an explosive hazard to be present in MRS 08.

The exposure pathway between recreational users and MEC is limited but complete. An unacceptable hazard is present within the 306 terrestrial acres of MRS 08.

1.3.3 MRS 09- Soldado Point Mortar and Bombing Area

Two Mk 25 Marine Markers (reported as MEC) were found on the ground surface near the water in close proximity to each other in MRS 09. Further evaluation indicated the Marine Markers were expended and not likely MEC. However, the shape of the items inhibited full evaluation, and therefore the items were destroyed by demolition. Marine Markers are used in both civilian and military marine activity and it is not certain the items were related to DoD site use. The items likely washed on shore after deployment over water. MD consisting of unidentifiable fragmentation, M9 fuze parts, and base plates were also found at the MRS. Historical ranges shown in relation to the RI MEC investigation for MRS 09 are provided in Appendix A: Figure A-33.

Historical data provided in the Culebra ASR (USACE 1995) and Culebra ASR Supplement (USACE, 2005) for MRS 09 indicate that beach F-3 (Point Soldado Beach) was used for mortar, 30 and 50 caliber firing area from boats to shore. Also, 30-pound fragmentation bombs and possibly 100-pound demolition bombs were used against silhouette targets on beach F-3. Sueño Cove was reported as a bombing target in which 30-pound and 1,000-pound bombs were dropped against waterborne targets. U.S. Army infantry and U.S. Marine movement exercises and small arms training were conducted on Soldado Point. No targets within the interior acres of MRS 09 were identified in the historical documents and there have been no reports of MEC discoveries or disposal by authorities or EOD Teams for MRS 09. No concentrated munitions use areas (which would indicate a potential for MC contamination) were identified during the RI field work. MD recovered from grids confirms the presence of 4.2-inch high explosive (HE) mortars given evidence of functioned M9 point detonating (PD) fuzes; however, no evidence of HE aerial bombs were recovered in MRS 09.

In accordance with the WP, field teams completed 3.35 acres of underwater visual transects, exceeding the planned acreage of 3.10 transect acres. As indicated previously in this section, historical evidence indicates that Sueño Cove was suspected of containing a bombing target within the underwater acres of MRS 09 and the northwest beach area of Soldado Point was also identified as a mortar target area. The underwater visual transects did not reveal evidence of target areas or high munitions use areas (MEC, MD, target remnants, etc.). Additional transects were placed within Sueño Cove to further investigate the reported bombing target area and along the northwest beach areas but these produced no evidence to indicate DoD munitions use.

Part of MRS 09 is managed by the PRDNER and residential development is not currently allowed on the site; however, several shacks and small structures are present in the southeastern portion of the MRS. Several structures are located in the northwestern portion of the MRS in areas not managed by the PRDNER. Potential current and future receptors include residents, construction workers, on-site workers, recreational users, and trespassers. Access throughout the MRS is unrestricted. Sensitive ecological receptors are present.

Given the evidence supporting the presence of expended 4.2-inch mortars, a potential exists for human and ecological exposure to HE MEC in MRS 09.

Based on evidence of MEC presence on the MRS and the likelihood of exposure of site visitors to the presence of these items, there is an unacceptable hazard at the 197.4 terrestrial acres of MRS 09.

1.3.4 MRS 10 - Defensive Firing Area No. 1

No MD items were recovered in MRS 10 during the RI; therefore, the potential for humans to encounter MEC at the remaining areas of MRS 10 is considered low. Historical ranges depicted in relation to the RI MEC investigation for MRS 10 are provided in Appendix A: Figure A-34.

Underwater visual transects did not reveal any evidence of target areas or high munitions use areas (MEC, MD, target remnants, etc.). There is no historical evidence of waterborne or underwater targets for MRS 10.

Historical records indicate that various land areas of MRS 10 were used by the Marine Corps for maneuvers; therefore, potential exposure to an explosive hazard cannot be completely ruled out. However, no evidence was found to indicate an unacceptable hazard is present.

MRS 10 is almost entirely privately owned except for municipal lands such as the police and fire stations. Residences are concentrated toward the shoreline along the northern areas of the MRS, and scattered toward the in land in the south eastern areas. Some residential areas have been developed on the hills overlooking the potential mortar impact areas. Increased development is likely in the future. Potential current and future receptors include residents, construction workers, onsite workers, recreational users, and trespassers. Access throughout the MRS is unrestricted. Sensitive ecological receptors are present.

Although historical evidence indicates training may have been conducted in parts for the MRS, no MEC or MD were found in the RI investigation. The RI concluded that there are no unacceptable hazards present for site users at the 522 terrestrial acres of MRS 10.

1.3.5 MRS 11 - Defensive Firing Area No. 2

Based on the differing levels of MEC hazard present in the northern and southern areas of the MRS, MRS 11 is recommended to be divided into two separate MRSs (MRS 11 North and MRS 11 South). The recommended divisions for MRS 11 are located in Figure 1-3. Intrusive results for MRS 11 yielded higher densities in grids that were closer to the NWP Bombardment Area. MD items, indicative of HE, were also recovered on the beach portions (Tamarindo Beach), which is a popular tourist location. MRS 11 North is approximately 3,200 ft from the southernmost boundary of the Aircraft Bombing and Machine Gun Range, found in the NWP. Given the proximity to the NWP and the heavy use of NWP, it is likely all MD in MRS 11 North originated from targets at the NWP. One other significant nearby target was discovered outside of MRS 11, a mortar target located on Stream Point. But due to the distance away, and the types of munition used, it is unlikely the fragmentation from the target impacted MRS 11. MRS 11 North is within the fragmentation distance of multiple targets on the NWP. These included aircraft-dropped bombs larger than 500 lb and projectiles larger than 8 in. targeting and impacting areas north of the Aircraft Bombing and Machine Gun Range and naval gun safety line found in NWP. Historical training areas depicted in relation to the RI MEC investigation for MRS 11 are shown in Appendix A: Figure A-35.

During the visual investigation of the underwater acres of MRS 11 performed with the ROV, an item of interest was identified in MRS 11 South. This item could not be confirmed as munition related but will be evaluated along with the MRS 12 in an underwater investigation during a separate underwater RI. No MEC or MD was found at the terrestrial acres of MRS 11 South.

The majority of MRS 11 is composed of private residences and industrial areas. Most development is concentrated in the southern portion of the MRS. A landfill is located in the northern portion of the MRS. Other areas contain undeveloped tracts that are steep with heavy vegetation. Potential current and future receptors include residents, construction workers, onsite workers, recreational users, and trespassers. Access is unrestricted throughout the MRS. Sensitive ecological receptors are present.

Although development is less concentrated in the northern portion of the MRS, access is unrestricted and all receptors mentioned above are present.

There is no unacceptable MEC hazard present for residents, recreational users, construction workers, or site visitors within the 498.2 acres of MRS 11 South.

Given the presence of MD indicative of MEC and the proximity to the NWP where extensive training with HE items was conducted, an unacceptable hazard is present for residents, recreational users, construction workers, or site visitors in the 196.1 acres of MRS 11 North. The recommended divisions for MRS 11 are depicted on Figure 1-3.

1.3.6 MRS 13 - Cayo Luis Peña Impact Area

During the post-award site visit, MD items [105 mm (HE and illumination); 5- and 3-inch projectiles; flares; and fuzes] were noted at 112 locations on MRS 13 (Appendix A: Figure A36). During the subsequent RI field work, multiple MD items were recovered on MRS 13 including a BDU-33, empty 5-inch illumination projectile and MD fragments.

Underwater visual transects were conducted inside of the 100-yd water boundary per the WP (USA 2011) and the PWS to determine if suspected MEC items on the seafloor were present within MRS 13 accessible water areas per the transect design. During the visual investigation along transects in the North of MRS 13, 39 items were observed that were either suspect MEC or that had the appearance or shape of munitions or MD.

The potential for exposure to MEC in MRS 13 exists for recreational users who frequent the beach areas. An unacceptable MEC hazard is present in MRS 13.

1.4 MC

Environmental samples were collected in soil, surface water, and sediment. Soil samples were collected at locations associated with items identified as MEC and MD, and at locations before and after detonations. Background surface soil samples were collected within eight soil types for use in determining background metals concentrations. The soil samples were analyzed for explosives and MC metals. Background surface water samples were collected from Cornello Lagoon in MRS 11. A baseline risk assessment was performed with further evaluation for samples with exceedances.

The baseline MC risk assessment followed a phased approach starting with simple screening level risk assessment (SLRA) and moving toward a more complex, site-specific deterministic

risk assessment to evaluate the magnitude of the risk at the site. The results of the risk assessment aid in the development, evaluation, and selection of appropriate response alternatives.

The following sections summarize the MC characterization results for each MRS.

1.4.1 MRS 06 - Artillery Firing Area

A separate evaluation of MC for the northern and southern portions of MRS 06 was completed to provide a more accurate representation of the potential risks to human and ecological receptors at this site due to the MRS geography. The MRS is not recommended to be administratively separated on this basis.

There are no exceedances of Human Health screening values, and therefore no unacceptable risks from former DoD munitions use were identified to human health from exposure to surface soil at MRS 06, based on the results of investigations conducted.

Historical research indicates that MRS 06 South was a firing point with no known targets located within the MRS. Historical documentation indicates the only munition fired from MRS 06 containing barium was the Stokes Mortar. The Stokes Mortar was fired from MRS 06 (South) towards floating water targets in Mosquito Bay. No evidence was found indicating that the Stokes Mortar was fired at targets located in MRS 06 North. There is no physical evidence of munitions use of MRS 06 as a target area.

Barium was detected in soil at concentrations greater than the ecological screening value. Barium is present at high naturally occurring concentrations in the soils of Culebra, and the maximum concentration detected at MRS 06 (1,100 mg/kg) only exceeded the established naturally occurring background value (710 mg/kg) by a factor of 1.5. As noted above, the Human Health screening value (1,500 mg/kg) was not exceeded. Naturally occurring barium values on the island have a high variability and range from 38 to 960 mg/kg. There is no evidence to support the Stokes mortar was fired from or impacted the ground in the vicinity of the barium exceedance at MRS 06 North (as noted above, the Stokes mortar is only associated with operations in MRS 06 South near Mosquito Bay). The location of the barium exceedance and the location of the area of the MRS 06 where munitions containing barium were fired are on opposite sides of the MRS. Only one fragment in which the munition source is unidentified was discovered at the site. One fragment does not identify a high-density anomaly area indicating a target area. Since barium does not correlate with former DoD activities within the northern area of the MRS, it is likely naturally occurring or is the result of sources other than DoD munitions use. Therefore, the elevated barium concentration is not considered to be related to former military munitions use at MRS 06.

No MC source of release was identified at MRS 06 during the RI. The RI concluded no unacceptable risks to human health or ecological receptors attributable to MC were identified in the MRS, based on results of investigations conducted.

1.4.2 MRS 08 - Cayo Norte Impact Area

There were no exceedances of screening values in the soil samples collected in MRS 08. Therefore, the RI concluded no unacceptable risks to human health or ecological receptors due to exposure to surface soil attributable to MC were identified in MRS 08. This conclusion is based on the results of investigations conducted.

1.4.3 MRS 09 - Soldado Point Mortar and Bombing Area

There are no exceedances of Human Health screening values, and therefore, the RI concluded no unacceptable risks attributable to MC were identified to human health due to exposure to surface soil, surface water, or sediment at MRS 09. This is based on the results of the investigations conducted.

At MRS 09, the RI concluded no unacceptable risks were identified for ecological receptors from exposure to soil or surface water, based on the results of the investigations conducted.

Aluminum and copper were detected in sediment at concentrations greater than the respective ecological screening values. The RI background value used for comparison for aluminum and copper in sediment is established to be 57,000 mg/kg and 310 mg/kg respectively. The maximum detected sediment concentration for aluminum and copper is 68,000 mg/kg and 390 mg/kg respectively. The naturally occurring concentration of aluminum and copper in the *Rs* soil type is high. This is the predominant soil type that drains into the lagoon sampled. No suitable locations for background sediment samples were available; therefore, the background values established for soil were used for sediment comparison, which likely underrepresents the true sediment background values. The sediment at MRS 09 was sampled in a collection lagoon that does not have an outfall or discharge in any way to other surface water bodies. Anthropogenic sources (illegally dumped trash and metallic debris) were observed in the lagoon during fieldwork. Thus, it is likely that naturally occurring concentrations of metals in the soils eroding from the surrounding hillsides, in combination with added aluminum and copper that sorbed from solution onto sediment particles during transport are responsible for the elevated concentrations in the lagoons. The concentrations were likely increased more by aluminum and copper that leached from anthropogenic sources in the lagoon. No explosives were detected in the sediment samples, which further supports the evaluation that the elevated concentrations were not from a MC source. The main sources of aluminum (rockets) and copper (rotating bands from projectiles), are not found in the same munition types (e.g. aluminum is not found in both rockets and projectiles, etc.) further indicating MD or MEC to be unlikely sources of these two metals in combination. There was no physical evidence of rockets or projectile target areas or of any target areas within MRS 09. Historical evidence does not indicate that MRS 09 was ever used as a target area for rockets or projectiles. Thus, based on the results of sampling conducted at this MRS and evaluation of the surrounding area, aluminum and copper are not considered to be related to former munitions use at MRS 09. No unacceptable risks to ecological receptors due to exposure to sediment attributable to MC were identified in MRS 09, based on the results of the investigations conducted.

No MC source of release was identified at MRS 09. In the absence of an identified MC source at MRS 09, the RI concluded no unacceptable risks to human health due to exposure to groundwater attributable to MC is expected, based on the results of the investigations conducted.

1.4.4 MRS 10 - Defensive Firing Area No. 1

Environmental samples were not collected in MRS 10 since no MEC or MD was found and no evidence of concentrated munitions use was discovered during the RI field work. Given no MC source of release was identified at MRS 10, the RI concluded no unacceptable risks to human health or ecological receptors attributable to MC were identified in the MRS. The conclusion is based on results of the investigations conducted.

1.4.5 MRS 11 - Defensive Firing Area No. 2

There are no exceedances of human health screening values, and therefore the RI concluded no unacceptable risks to human health due to exposure to surface soil, surface water, or sediment attributable to former munitions use were identified at MRS 11 North or MRS 11 South. The conclusion was based on results of investigations conducted.

Target areas identified through historical research resided solely on the beaches of Firewood Bay and no target areas were placed within the interior of MRS 11. The target areas along the beaches were rocket barrage targets and 81mm mortar targets (the firing point for the 81mm mortars was also located in MRS 11). MRS 11 borders NWP and is approximately 3,200 ft from the southernmost boundary of the Aircraft Bombing and Machine Gun Range which is found in NWP. The Aircraft Bombing and Machine Gun Range boundary crosses the safety line that was established for range use and provided a buffer area to ensure munitions were not fired to the south of the safety line. The NWP Aircraft Bombing and Machine Gun Range targets were established to the north of this safety line. The other significant target outside of MRS 11 was a mortar target on Stream Point but fragmentation from the target is not anticipated to have reached the grids in MRS 11 North where fragments were discovered. The discovery of munitions fragments in MRS 11 North is most likely the result of DoD use of the target areas located within the NWP and not the result of newly discovered targets on MRS 11 North. MRS 11 North is within the fragmentation distance of aircraft-dropped bombs larger than 500 lb and projectiles larger than 8 in. targeting and impacting areas north of the Aircraft Bombing and Machine Gun Range and naval gun safety line boundary (see Appendix A: Figure A-2). Only small quantities of MD (17 pieces of munitions fragments equating to approximately 3.4 lb of MD), were found above the beach areas. The beach areas produced two MD items (an expended BDU 33 and an empty 5-inch illumination projectile. No MEC was discovered, nor were any target remnants or other indicators that would support heavy DoD munitions use. No target areas within MRS 11 were identified.

MRS 11 South produced no MEC or MD. Per the RI WP, if no evidence of munitions-related activities in a given area (e.g., MEC, MD/fragments, target berms, ground scars) was identified, then there was no reason to expect that MC would have been released in that area. Therefore, the MC sampling effort that focused on determining the presence of MC contamination associated with evidence of munitions-related activities was not applicable and MC sampling was not conducted in MRS 11 South.

The 2007 SI also supports the RI findings as the SI fieldwork found no MEC in either area; only one MD item in MRS 11 North and no MD in MRS 11 South was found.

MC sampling of MRS 11 North produced soil samples with detections of mercury with one sample containing a mercury concentration exceeding its Preliminary Screening Value (PSV).

The maximum detected concentration of mercury (0.4 mg/kg) did not exceed the human health screening value (1.0 mg/kg); therefore, no risk to human health is expected from exposure to soil at MRS 11. The background value established for mercury comparison in the DeE2 soil type where the exceedance occurs at MRS 11 is 0.051 mg/kg. Background values for mercury are highly variable on the island and range from 0.032 to 0.6 mg/kg.

Mercury was detected in soil at a concentration greater than the ecological screening value. The one soil sample with mercury detected at a concentration exceeding its PSV was in close

proximity to three other samples with mercury detected at concentrations below the PSV; therefore, the mercury exceedance is considered a localized occurrence. The munitions documented as used on MRS 11 are not known to use mercury fulminate as part of the explosive train. Mercury fulminate is used as an initiating explosive in very small quantities as a primer or detonator. Mercury was identified in the soil but not in conjunction with any other explosive constituents as would be anticipated if it were the result of munitions use. Mercury fulminate is used in extremely small quantities (usually measured in milligrams per item) as compared to the boosters and main explosive charges of munitions. The boosters and main charges of the munitions represent the majority of the explosive weight. Therefore, since no explosive constituents were present at the location of the elevated mercury detection, the exceedance is not considered attributable to military munitions use.

Based on the localized occurrence of the exceedance and the concentration falling in the range of mercury background concentrations that occur naturally on Culebra Island in other soil types, no unacceptable risk to ecological receptors is expected to occur from to exposure to soil at MRS 11.

Based on results of the baseline risk assessment and a review of the MC risk assessment Data Quality Objectives (DQOs), the RI concluded no unacceptable risks to human health or ecological receptors related to former military munitions use were identified at MRS 11. The conclusion is based on the investigations conducted.

Since no concentrated munitions use areas were identified at the MRS, and sampling indicated no MC source is present in surface soil at MRS 11, the RI concluded no unacceptable risks to human health attributable to MC from exposure to groundwater are expected. Any future groundwater contamination detected downgradient of the landfill would likely be attributable to the Municipality of Culebra, identified as a potentially responsible party, due to use of the unlined landfill. Contamination upgradient or cross gradient of the landfill would not likely be related to the landfill unless it were located immediately adjacent to the landfill.

1.4.6 MRS 13 - Cayo Luis Peña Impact Area

There were no exceedances of MC screening values in the soil samples collected in MRS 13. Therefore, the RI concluded no unacceptable risks to human health or ecological receptors related to former munitions use were identified in MRS 13, based on the results of investigations conducted.

No MC source of release was identified at MRS 13. Therefore, since no MC source was identified, the RI concluded no unacceptable risks to human health related to former munitions use are expected in MRS 13 associated with groundwater exposure.

1.5 CONCLUSIONS AND RECOMMENDATIONS

Based on the results and conclusions of the RI, the following recommendations are made for the terrestrial portions of the six MRSs investigated in this RI: MRS 06, MRS 08, MRS 09, MRS 10, MRS 11 and MRS 13.

The RI was conducted in accordance with the USACE-approved RI WP. The data were used to support a risk assessment approach as agreed upon by the TPP team. FS recommendations for each MRS are presented below.

1.5.1 MRS 06 - Artillery Firing Area

1.5.1.1 MEC

MRS 06 was used as a firing point, based on historical documents there have been no past discoveries of MEC and the RI field work found no evidence to support that a MEC hazard exists at the MRS, however, as with all of Culebra, it is possible that MEC may exist in MRS 06 due to its use as a firing point but the MEC hazard is considered low. MRS 06 is recommended to proceed to an FS for the negligible MEC hazard.

1.5.1.2 MC

Based on results of the baseline risk assessment and a review of the MC risk assessment DQOs, no MC source of release was identified at MRS 06. The RI concluded no unacceptable risks (to human health or ecological receptors attributable to MC were identified in MRS 06. This conclusion is based on results of the investigations conducted. A FS to evaluate MC is not warranted.

1.5.2 MRS 08 Cayo Norte Impact Area

1.5.2.1 MEC

The exposure pathway between residents, construction workers, on-site workers, recreational users, and trespassers and MEC is limited but complete. An unacceptable hazard is present within the entire 306 terrestrial acres of MRS 08. MRS 08 is shown in Appendix A: Figure A-32. A FS for development and evaluation of alternatives for a MEC remedial response for the entire MRS is recommended.

1.5.2.2 MC

Based on results of the baseline risk assessment and a review of the MC risk assessment DQOs, the RI concluded no unacceptable risks to human health or ecological receptors attributable to MC were identified in MRS 08. This conclusion is based on results of the investigations conducted. Therefore, MC will not be evaluated in the FS.

1.5.3 MRS 09 - Soldado Point Mortar and Bombing Area

1.5.3.1 MEC

Two items (expended Mk 25 Marine Markers evaluated as MEC at the time of discovery due to the shape of the item inhibiting full evaluation) were recovered from MRS 09. The items are used in both civilian and military marine activity and it is not certain the items are attributable to military training in the area.

Based on evidence of MEC presence at the MRS and the likelihood of exposure of site users (residents, construction workers, on-site workers, recreational users, and trespassers) to the presence of these items, there is an unacceptable hazard at the 197.4 terrestrial acres of MRS 09. MRS 09 is shown in Appendix A: Figure A-33. A FS for development and evaluation of alternatives for a MEC remedial response for the entire MRS is recommended.

1.5.3.2 MC

Based on results of the baseline risk assessment and a review of the MC risk assessment DQOs, the RI concluded no unacceptable risks to human health or ecological receptors attributable to MC were identified in MRS 09. The conclusion is based on results of the investigations conducted. Therefore, MC will not be evaluated in the FS.

1.5.4 MRS 10 - Defensive Firing Area No. 1

1.5.4.1 MEC

Although historical evidence indicates training may have been conducted in parts of the MRS, no MEC or MD were found in the RI investigation. The RI concluded no unacceptable hazard is present at the 522 terrestrial acres of MRS 10.

Based on the results of the study the southern acres of MRS 11 is recommended to be transferred to MRS 10. The southern 498.2 acres of MRS 11 have been evaluated with no unacceptable MEC hazard present. The acreage recommended for transfer includes the highly developed portions of Dewey and a small portion of the airport. The addition of this acreage would increase MRS 10 from 522 acres [as listed in FUDS Management Information System (FUDSMIS)] to 1020.2 acres.

No FS is warranted to address MEC hazards at the original acreage of MRS 10 or the acreage transferred into MRS 10 from MRS 11.

1.5.4.2 MC

Environmental samples were not collected in MRS 10 since no MEC or MD and no evidence of concentrated munitions use was discovered during the RI fieldwork. Given no MC source of release was identified at MRS 10, the RI concluded no unacceptable risks to human health or ecological receptors attributable to MC were identified at the 522 acres of MRS 10. A FS to evaluate MC is not warranted.

Given no MC source of release was identified at the southern acres of MRS 11, the RI concludedno unacceptable risks to human health or ecological receptors attributable to MC were identified. This conclusion is based on the results of the investigations conducted. The southern 498.2 acres of MRS 11 are recommended to be transferred into MRS 10.

A FS to evaluate MC is not warranted for MRS 10.

1.5.5 MRS 11 - Defensive Firing Area No. 2

1.5.5.1 MEC

Based on the differing levels of MEC hazard present in the northern and southern areas of the MRS, MRS 11 is recommended to be divided. Because MD indicative of MEC was recovered in only the northern acreage, and the proximity of the Bombardment Areas of NWP, MRS 11 is recommended to be divided into MRS 11 North and MRS 11 South. The original acreage of MRS 11 and the recommended division of the MRS are shown in Figure 1-3.

The negligible hazard to residents, recreational users, construction workers, and site visitors at the 498.2 acres of MRS 11 South is acceptable; therefore, a FS for MRS 11 South is not

warranted. The 498.2 acres of MRS South are recommended to be transferred to MRS 10 (also negligible MEC hazard and similar receptors) located to the southeast.

An unacceptable MEC hazard is present in the 196.1 acres of MRS 11 North. Given the presence of MD indicative of MEC and the proximity to the NWP where extensive training with HE items was conducted, an unacceptable hazard is present for residents, recreational users, construction workers, or site visitors. A FS for development and evaluation of alternatives for a MEC remedial response for MRS 11 North is recommended.

1.5.5.2 MC

Based on minimal findings of MD and the MC risk assessment, the RI concluded there are no unacceptable risks to human health or ecological receptors related to former military munitions use were identified at MRS 11. This conclusion is based on results of the investigations conducted.Therefore, MC will not be evaluated in an FS for MRS 11 North. A FS to evaluate MC is not warranted for MRS 11 South. The 498.2 acres of MRS 11 South are recommended to be transferred into MRS 10.

1.5.6 MRS 13- Cayo Luis Peña Impact Area

1.5.6.1 MEC

The potential for human exposure to MEC in MRS 13 exists for the recreational users that frequent the beach areas. An unacceptable MEC hazard is present in the 334.2 terrestrial acres of the MRS, and therefore, a FS for development and evaluation of alternatives for a MEC remedial response is recommended.

1.5.6.2 MC

Based on results MC risk assessment, the RI concluded there are no unacceptable risks to human health or ecological receptors attributable to MC identified in MRS 13. This conclusion is based on results of the investigations conducted.Therefore, MC will not be evaluated in an FS for MRS 13.

Table 1-4 summarizes the MEC and MC terrestrial characterization presented above for MRS 06, 08, 09, 10, 11, and 13. As noted above, the conclusions and recommendations of this report apply only to the terrestrial acres of the six MRSs addressed in this RI. Information pertaining to underwater investigation was presented for support of the terrestrial investigation only.

Underwater visual transects were conducted inside of the 100-yd water boundary per the WP (USA, 2011). This aided in determining if suspected MEC items on the seafloor were present within the MRS accessible water areas per the transect design. The visual investigation along the transects for MRSs 11 and 13 produced either suspect MEC items or items that had the appearance or shape of munitions, munition remnants, or MD. No suspect MEC items or items of interest were found in MRS 06, 08, 09, or 10. The underwater portions of MRS 09 and MRS 13 are evaluated in a separate RI/FS. MRS 12 encompasses the underwater acres of MRS 10 and 11 (ocean side of the MRSs) is also investigated and evaluated by a separate RI/FS. The bay side underwater acres of MRS 10 and MRS 11, along with underwater acres of MRS 06 and 08, currently have not been identified for an RI/FS.

Table 1-4: MEC and MC Terrestrial Characterization Summary

MRS	Land Use		Unacceptable MEC Hazard Present? (1)	Unac-ceptable MC Risk Present? (2)	FS Recommended?
	Current/Future	Accessibility			
MRS 06 (826 acres)	Residential / Residential	Limited Steep, rugged terrain and vegetation limit access to the interior	Unknown (MD) Unresolveable datagap due to ungranted ROE.	Unknown, but likely not.	Yes FS for evaluation of remedial alternatives for potential MEC hazard.
MRS 08 (306 acres)	Part-Time Residential / Residential or Resort	Limited (by boat only, steep rugged terrain)	Yes (MD)	No	Yes FS for evaluation of remedial alternatives for MEC hazard.
MRS 09 (197.4 acres)	Nature Preserve, Residential / Residential or Resort	Limited Steep, rugged terrain and vegetation limit access to the interior	Yes (MEC MD)	No	Yes FS for evaluation of remedial alternatives for MEC hazard.
MRS 10 (522 acres) If MRS 11S transferred in: (1020.2 acres)	Residential / Residential	Full, Unlimited	No	No	No No unacceptable MEC hazard identified.
MRS 11 North (196.1 acres)	Mixed Residential, Landfill / Mixed Residential, Landfill	Limited Steep, rugged Terrain and vegetation limit access to the interior	YES (MD)	No	Yes FS for evaluation of remedial alternatives for MEC hazard.
MRS 11 South (498.2 acres)	Mixed Residential/ Mixed Residential	Limited Steep, rugged terrain and vegetation limit access to the interior	No	No	No No unacceptable MEC hazard or MC risk identified. Recommend transfer to MRS 10.
MRS 13 (334.2 acres)	Nature Preserve / Nature Preserve	Limited (access by boat only, steep rugged terrain present)	Yes (MD)	No	Yes FS for evaluation of remedial alternatives for MEC hazard.

(1) No evidence of concentrated munitions use found in any MRSs investigated.

(2) No unacceptable MC risks identified to human health or ecological receptors in MRS 06, MRS 08, MRS 09, MRS 10, MRS 11 or MRS 13. Therefore, no evaluation of MC in an FS is warranted.

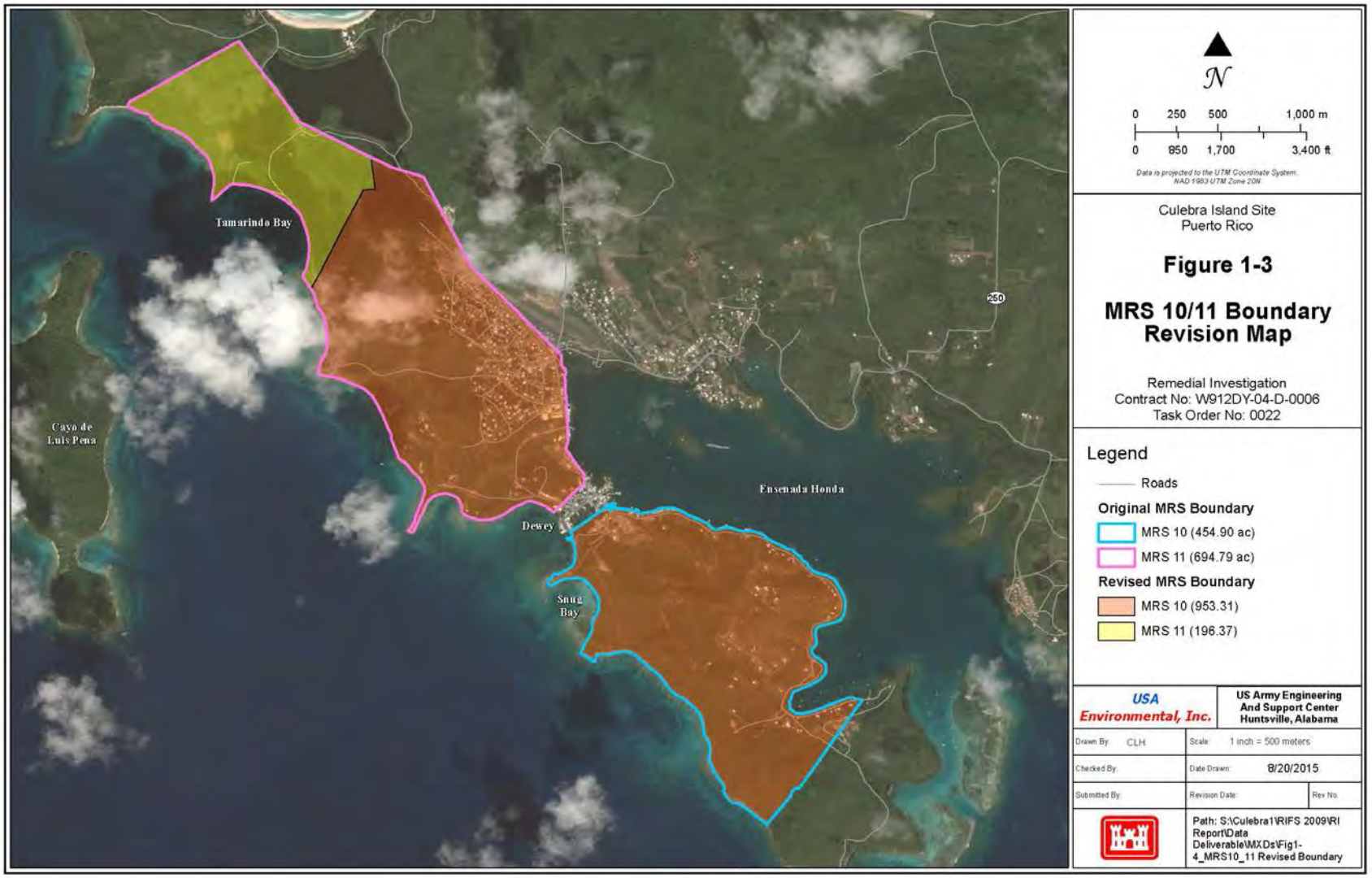

Figure 1-3: Recommended Delineation for MRS 10 and MRS 11

CHAPTER 2. INTRODUCTION

2.1 PURPOSE

The primary purpose and scope of this project is to perform a RI designed to gather the data necessary to determine the nature and extent of MEC and MC contamination on six of the 13 MRSs identified on Culebra Island:

- Artillery Firing Area (MRS 06) – Project No. I02PR006806
- Cayo Norte Impact Area (MRS 08) – Project No. I02PR006808
- Soldado Point Mortar and Bombing Area (MRS 09) – Project No. I02PR006809
- Defensive Firing Area No. 1 (MRS 10) – Project No. I02PR006810
- Defensive Firing Area No. 2 (MRS 11) – Project No. I02PR006811
- Cayo Luis Peña Impact Area (MRS 13) – Project No. I02PR006813

Note: An INPR revision prepared in 2017 following the conclusion of RI fieldwork separated MRS 09 and MRS 13 by land and water areas, with the land areas retaining the original MRS number and project numbers. This RI Report addresses the land areas. The water areas are addressed in a separate RI Report. MRS 09 was divided into two MRSs: MRS 09 - Soldado Point Land Area (Project No. I02PR006809) and MRS 19 - Soldado Point Water Area (Project No. I02PR006819). MRS 13 was divided into one land area, MRS 13 - Cayo Luis Peña Land Area (Project No. I02PR006813); and two water areas based on explosive hazard present, MRS 17 - Cayo Luis Peña North Water Area (Project No. I02PR006817) and MRS 18 - Cayo Luis Peña South Water Area (Project No. I02PR006818).

This RI Report uses the acreages updated in the INPR revision for MRS 09 and MRS 13 (acreages will differ from acreages published in the Formerly Used Defense Sites Management Information System Database [FUDSMIS]. Since the 2017 INPR had not been finalized at the time of publication of the RI Report, the original MRS names for MRS 09 and MRS 13 are retained.

The data will be used to assess hazards that are associated with MEC and to conduct a baseline risk assessment for human health and the environment. Where unacceptable MEC hazards or MC risk is defined, the results of the RI will be used to develop and evaluate alternatives in the FS. This RI report addresses the terrestrial portions of the MRSs only. Available information on investigation of the underwater acres of the MRSs is included to support the terrestrial investigation. The RI and FS for the underwater portions of these MRSs will be evaluated in separate documents. The remaining MRSs will be addressed under separate contracts. The conclusions and recommendations of this report apply only to the terrestrial portions of the six MRSs addressed in the RI.

2.2 PROPERTY DESCRIPTION AND PROBLEM

2.2.1 Location

The project location is Culebra Island (MRS 06, 09, 10, and 11), approximately 17 miles east of the main island of Puerto Rico and also includes surrounding islands Cayo Luis Peña (MRS 13), located approximately three-quarters of a mile off the western coast of Culebra Island and Cayo

Norte (MRS 08), located approximately one-half mile off the northeast coast of Culebra Island. Culebra Island and the surrounding cays are part of the Commonwealth of Puerto Rico. This RI addresses the terrestrial portions of the six MRSs only. The underwater portion of the MRSs is not evaluated in this document. Details of the underwater portion of the MRS are presented when relevant to support the evaluation of the terrestrial acreage. The site location is shown in Figure 1-1. MRS locations are shown on Figure 1-2. Appendix A: Figure A-1, Plate 2 from the ASR shows historical areas of DoD activity.

2.2.1.1 MRS 06 – Artillery Firing Area

MRS 06 is on the eastern end of Culebra extending from a point at the most northern tip of Mosquito Bay, northeast to a point just west of Duck Point, and east to the end of the island. This area consists of 826 land based acres and was used by the Marines for artillery firing points for exercises conducted from 1922 through the 1940s (USACE, 2005a). As documented in Fleet Landing Exercise (FLEX) #2 in the ASR Supplement (USACE, 2005), exercises involving small arms, 75 mm pack howitzers, 3-inch Stokes mortars, and 37 mm HE projectiles were conducted from the Mosquito Bay area in 1936. The targets identified were rafts placed in East Channel simulating an advancing boat or into the 37mm impact area also located in East Channel. Beginning in 1936, the Marines fired 75mm projectiles from a firing point inland of Mangrove Bay at Weather Channel near Culebrita. Additionally, in 1937, U.S. FLEX No. 4 involved use of the lagoon area at the back of Mosquito Bay. In 1939, the Marines fired from 1,000 yards northeast of Mosquito Bay toward the cays to the east. From Mosquito Bay, 37mm projectiles were fired west to water targets between Point Vaca and Snapper Shoal (USACE, 2004). There have been no reports of MEC discoveries or disposal by authorities or EOD Teams for MRS 06.

Currently, this MRS is almost entirely privately owned with residences scattered throughout. The PRDNER has jurisdiction over a 1,000-m wide belt of all Puerto Rico's coastal lands or additional distances needed to protect key coastal natural systems, the territorial waters, and submerged lands beneath them extending nine nautical miles offshore. The USFWS co-manages the coastal zone as part of the CNWR. MRS 06 has unrestricted public access; however, vegetation and terrain serve as a natural barrier limiting access to portions of the MRS.

2.2.1.2 MRS 08 – Cayo Norte Impact Area

MRS 08 includes only Cayo Norte and covers approximately 306 acres of land. Cayo Norte was leased by the Marines for training; however, it has not been determined from records whether the site was ever used for training (USACE, 2005a). There are no underwater acres for MRS 08. This lease was ended as part of the agreement between the Navy and the Mayor of Culebra in 1971. Notes on FLEX No. 5 indicate that impact of Cayo Norte was planned but that difficulties clearing people and cows from the island kept it from being used for an impact area. The surrounding waters to the east of the Cayo Norte may contain suspected 5-inch high velocity aircraft rocket (HVAR) from adjacent MRSs. No unexploded ordnance (UXO) has previously been documented as found on Cayo Norte (USACE, 2005b). Cayo Norte is privately owned. [Center for Collection of Municipal Revenues (CRIM, 2011)]. During discussions with the land owner it was determined the cayo is zoned as R-0 (25 c), which allows for very low density residential development, at one home per 25 acres. The source of fresh water for the residential properties is from rain water collected from rooftops and/or the desalination of salt water, using solar energy to power a package desalinator. The landowner also commented that he was not

aware of any viable source of groundwater on the Cayo. No MEC items have been discovered by the land owner.

2.2.1.3 MRS 09 – Soldado Point Mortar and Bombing Area

MRS 09 consists of 329.2 acres (197.4 land acres, 131.8 water acres) on the very southern tip of the southern peninsula of Culebra. Underwater portions of this MRS are evaluated in a separate document; however, details of the underwater portion of the MRS are presented when relevant to the evaluation of the terrestrial acreage. Several training exercises including mortar firing, suspected aerial bombing on water targets, and strafing were conducted on Soldado Point and the bay northwest of Soldado Point during the 1930s and 1940s (USACE, 2005a). The Supplemental ASR mentions that 30- and 1,000-pound bombs were dropped in Sueño Cove at waterborne targets (USACE 2005b). Munitions used on the beach (referred to as F-3 beach or Soldado Point Beach) in the bay Northwest of Point Soldado included 30-pound fragmentation bombs, possibly 100-pound demolition bombs, 81mm mortars, and small arms.

This piece of property was accepted in a quitclaim deed from the Secretary of the Interior by the Governor of Puerto Rico in 1982. This property is managed by the PRDNER; however, several shacks have been built along the water at Sueño Cove (CRIM, 2011).

2.2.1.4 MRS 10 – Defensive Firing Area No. 1

MRS 10 consists of 522 land acres on the southern peninsula of Culebra, south of the town of Dewey and north of MRS 09 (USACE, 2005a). Marines conducted amphibious landing and ground maneuver training using 81mm mortars on the beaches and hills in this area from the 1920s through the 1940s. Specifically, the hill on the north end of the MRS has been listed as a 1935 area of direct fire from 3" Common projectiles, and Snug Bay was shown as a 1935 water area for direct fire. Additionally a 1924 outpost and ammunition storage area is located on the north end of the MRS near Snug Bay (USACE, 2005b). MRS 10 has many residents and businesses. Most of the development is near the town of Dewey on the north end of the site; however, houses are scattered throughout the southeastern side of this MRS. This MRS is almost entirely privately owned except for municipality lands such as the police and fire stations. (CRIM, 2011).

2.2.1.5 MRS 11 – Defensive Firing Area No. 2

MRS 11 is located on the west side of Culebra between the NWP and the town of Dewey. The area is approximately 694.3 acres (USACE 2005a), and most of the southern portion of this MRS has been extensively developed for residential use. The areas along the beach and the west side of this site are less developed. There are no underwater acres for MRS 11. MRS 12 is adjacent and will be evaluated in a separate RI. The land is privately owned with some municipality properties such as the school, hospital, and government buildings (CRIM, 2011). An unlined municipal landfill is located in the northern portions of the MRS. Several training exercises were conducted in this area, including 75mm and 155mm firing from Firewood Bay at Mono Cay and portions of Cayo de Luis Peña in 1924; FLEX No. 4 with firing of small arms and 81mm mortars in 1936; and FLEX No. 7 in 1941 with boat-to-beach firing of 5-inch and 6-inch projectiles. (USACE, 2005b) There have been no documented reports of MEC discoveries or disposal by authorities or EOD Teams for MRS 11.

2.2.1.6 MRS 13 – Cayo Luis Peña Impact Area

MRS 13, Cayo de Luis Peña, with 334.2 acres of land and 872.6 total MRS acres (334.2 land acres, 538.4 water acres), is approximately three quarters of a mile off the western coast of Culebra. (USACE, 2005a). Underwater portions of this MRS are being evaluated under a separate document; however, details of the underwater portion of the MRS are presented when relevant to the evaluation of the terrestrial acreage. The northern tip of this island was used as a firing target during Marine exercises conducted between 1924 and 1941. Records show that 75mm projectiles were fired at the Cayo in 1924 and that 155mm, 37mm, 8-inch, and 6-inch projectiles may have also been used. In the 1960s, an observation point was erected on the hilltop on Luis Peña, including a run-in line, helipad, and living quarters. Cayo de Luis Peña is managed by the USFWS as part of the CNWR.

Note: In MRS 11 and 13 (overshoot zones from the NWP target area), there is evidence of Navy illumination rounds (cases), however these don't contain Explosive D filler. Based on data collected under other efforts and source information (2007 SI, ASRs), the target area for naval munitions is located on the NWP (MRS 02).

2.2.2 Topography

Culebra Island and the surrounding cays are comprised of sandy beaches, irregular rugged coastlines, lagoons, coastal wetlands, steep mountains, and narrow valleys. Ninety percent of the island is mountainous. The island contains an east-west trending ridge with an average elevation of 300 feet mean sea level (msl) in the northern part of the island. The highest point on Culebra is Mount Resaca at approximately 640 feet msl. Topographic features are shown on Figure 1-2.

Two Culebra Cayos are included in this RI. Cayo Norte (MRS 08) is a generally flat island with several hills on the western side. The elevation ranges from 80 to 300 feet msl. The shoreline on the north side of the island consists of cliffs dropping off to the water. The southern side slopes down to the water and contains beaches. The island consists of light to moderate vegetation with large open areas. There is one body of water on the south side of the island that is connected to the beach; it is most likely a large, brackish tidal pool.

Cayo Luis Peña (MRS 13) is comprised of sandy beaches, irregular rugged coastlines and steep mountains. A peak of 476 feet msl is located in the center of the Cayo and a smaller peak of 171 feet msl exists on the northern peninsula of the Cayo.

2.2.3 Climate

The weather on Culebra Island is generally warm year round due to its tropical marine climate. Based on the Charlotte Amalie HAR, Virgin Islands, weather station (1972 - 2012) located 20 miles to the east, yearly average rainfall is approximately 40.01 inches. The months of August through November are considered the wet season, and the driest months are January through April. Average daily temperatures range from an average maximum of 87.4 °F and an average low of 75.3°F. Winds are generally from the east-northeast during November through January and from the east during February through October. Yearly average wind speed is 8 knots. Hurricane season is from June through November, and severe hurricanes hit Culebra every 10 to 20 years. The average rainfall is provided in Table 2-1 [Southeast Regional Climate Center (SERCC, 2012)].

Table 2-1: Average Rainfall, Culebra Island Puerto Rico

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
inches	2.03	1.45	1.46	2.74	3.35	2.75	2.66	3.83	5.42	5.94	5.54	2.84	40.01

Source: SERCC, 2012

2.2.4 Vegetation

Vegetation is moderately to extremely dense on undeveloped portions of Culebra, Luis Peña, Northeast Cay, and Culebrita; however, vegetation is sparse or absent on many of the smaller cays as most are rocky with very little soil. Hazardous vegetation includes the Mesquite acacia or thorny brush, which may be present on Culebra and all of the surrounding cays, and the poisonous Manchineel tree (also called Manzanillo Tree or "Tree of Death"), which is known to be present on the NWP and near Flamenco Lagoon. Endangered vegetation includes the spineless Culebra Island cactus (*Leptocereus grantianus*).

2.2.5 Geology

Culebra Island and the surrounding cays are part of the Culebra Archipelago. Culebra is underlain mainly by mixed volcanic rocks which include lava, tuff, breccia, and tuffaceous breccia. Bedrock is exposed at land surface in 50 to 70 percent of the Island and a thin granulated soil (0.3 to 0.6 m thick) occurs in pockets between rocky areas [U.S. Geological Survey (USGS, 2002)]. Some small areas underlain by alluvium near the coast. The clastic sediments are present in small areas along the coast and within the small valleys incised by the intermittent streams (USGS, 1996). The rocks in the north-central portion of Culebra and on the east side of Cayo Luis Peña contain diorite porphyry inclusions and have little to no porosity due to compaction and quartz and calcite growth in the pore space (USACE, 1995).

2.2.6 Hydrology

There are no permanently flowing surface water streams on Culebra; potable water is obtained from Autoridad de Acueductos y Alcantarillados (AAA), a Commonwealth-owned utility that maintains a pipeline from the main island routed through the neighboring island of Vieques. Three large ephemeral streams drain the hills north of Great Harbor to the south, and one large ephemeral stream has developed along an old, washed-out jeep road on the north side of the island toward Brava Beach. These ephemeral streams generally carry water only after heavy precipitation. There are many small ephemeral gullies and ditches throughout the island, and several lagoons are present on Culebra as well (USGS, 1948).

The following sections describe the hydrology within each MRS.

2.2.6.1 MRS 06 – Artillery Firing Area

The heavily dissected terrain and moderate elevations ranging from sea level to over 225 feet msl, leads to multidirectional surface water flow patterns. The central portion of the MRS primarily drains in a temporal stream to Mangrove Bay to the southeast, the northeastern portion of the MRS primarily drains northeast between Duck Point and Larga Beach. A ridgeline keeps surface water draining from this MRS from draining into Zoni Lagoon. The central areas of the

MRS drain into Mosquito Bay. No significant volumes of fresh surface water are present within the MRS. Several small lagoons are scattered throughout the MRS.

2.2.6.2 MRS 08 – Cayo Norte Impact Area

Surface water on the island of Cayo Norte primarily drains in ephemeral streams radially into the ocean. Two intermittent streams drain the south facing slopes of the MRS into a lagoon located in the southcentral area of the MRS.

2.2.6.3 MRS 09 – Soldado Point Mortar and Bombing Area

Surface water in MRS 09 drains radially from elevations that rise to over 225 feet. One ephemeral stream drains into Ensenada Dakity. Two lagoons are present within the MRS, one due west of Ensenada Dakity, the other northwest of Sueño Cove. The lagoon northwest of Sueño Cove has no outflow. The areas in the northwest portion of the MRS drain into Ensenada Fulladosa. The north eastern areas either drain directly into Ensenada Honda, or into the lagoon west of Ensenada Dakity, which eventually flows either into Ensenada Honda or directly into the Atlantic Ocean. The Southeastern portion of the site drains into Sueño Cove. The Southwestern areas drain directly into the ocean.

2.2.6.4 MRS 10 – Defensive Firing Area No. 1

Surface water in MRS 10 drains in small ephemeral gullies radially from a central peak which rises to over 325 feet. Surface water from the northern areas of the MRS drains directly into Ensenada Honda, and the northeastern areas drain into Ensenada Fulladosa. The northwestern areas drain into a small inlet to the northwest of the MRS that is hydrologically connected to both Ensenada Honda to the east and Bahia De Sardinas to the west. No perennial surface water bodies are present.

2.2.6.5 MRS 11 – Defensive Firing Area No. 2

Surface water flow in MRS 11 is divided by a northwest/southeast trending ridgeline which rises to over 400 feet. Surface water from the northern areas drains into Flamenco Lagoon. The eastern side of the ridge drains to an ephemeral stream and eventually flows into Ensenada Honda. The western side of the ridge either drains to Cornello Lagoon located on the central western side, or to Canal Luis Peña. The northern areas of the western side drain to Tamarindo Bay.

2.2.6.6 MRS 13 – Cayo Luis Peña Impact Area

Surface water in MRS 13 drains radially in small ephemeral gullies from a central peak which rises to over 450 feet in the northern areas and from a smaller peak rising to approximately 150 feet in the southeastern areas. The northern portions of the smaller peak flow to a small unnamed lagoon. No significant volumes of fresh surface water are present within the MRS. A lagoon present on the northern edge of the southern lobe of the island is heavily influenced by tidal water.

2.2.7 Hydrogeology

Ground water in Culebra occurs in alluvial deposits and in the volcanic and plutonic rocks. Alluvial deposits are located along major stream valleys that reach the coast. The alluvium is mostly composed of silt and clay with limited quantities of sand and gravel. Fractures and joints within the volcanic and plutonic rock formations store water in small quantities. Most of these fractures and joints diminish in number and size with depth and pinch out at about 300-ft below land surface. Water-table conditions prevail in the bedrock aquifer (USGS, 2002).

No data are available to accurately map groundwater flow on Culebra. Given the fractured nature of the underlying volcanic and plutonic rock, confined aquifers are likely not present. It can reasonably be assumed the groundwater will flow from areas with higher potentiometric surfaces at higher elevations towards lower elevations, in the bays and ocean, taking the shortest path. The shortest path of flow would generally be perpendicular to topographic contours (Figure 1-2). Travel will be within fractures of the volcanic bedrock and within the patches of alluvial deposits. Travel within the fractures could follow a slightly diverted path, but general flow will be toward decreasing elevation contours to the nearest water body.

By comparing changes in water levels with records of well pumpage and estimates of recharge, the specific yield for the bedrock aquifer was estimated as less than one percent (USGS, 1996).

The majority of depths to groundwater range from 0 to 15 feet bgs near the shore line where most people are located, increasing as elevation rises to a maximum recorded value of 48-ft at higher elevations (USGS, 1995). The wells sampled in the RI reported depth to groundwater findings of 3.5 to 10.5 feet bgs in MRS 06, 21.4 ft bgs in MRS 09, and 18.3 feet bgs in MRS 11.

Historically, desalinated seawater and rooftop-rainfall catchments have served as primary sources for water supply. The Puerto Rico Aqueduct and Sewer Authority (PRASA) is responsible for freshwater supply and distribution to the public for the island. In the past, PRASA maintained a municipal well field of five wells as a major source of water for public supply. In 1971, a desalination plant was built to purify the well water which has a high mineral content and is unsuitable for drinking (USGS, 1995). Production in the well field is estimated to be less than 20 cubic meters per day (USGS, 2014), far less than the growing demands of the island. Currently water demands are met by water pumped in from Puerto Rico mainland. There are no indications that this will change in the future.

2.2.8 Sensitive Environments

The information identifying sensitive environments on Culebra was identified in a 2011 biological inventory found in Appendix Q (Gaddy, 2011). Table 2-2 lists all endangered, threatened, and otherwise protected species known to occur or potentially-occur on the island of Culebra and outlying cays. Species historically known to occur on Culebra and outlying cays are given in bold type. Species not listed in bold type are federally-listed species known to occur on Vieques, St. Thomas, or St. Croix that potentially-occur on Culebra and outlying cays.

Eighteen of the twenty-three species in Table 2-2 are federally-listed as endangered or threatened by the USFWS (USFWS, 2010b and USFWS, 2012c); four species are officially listed by the Puerto Rico Department of Natural Resources (Estado Libre Asociado de Puerto Rico). Departmento de Recursos Naturales y Ambientales, 2004), and one species (*Justicia culebritae*) is listed as a federal "species of concern."

Of the 23 species listed in Table 2-2, only one, *Eretmochelys imbricata* (hawksbill turtle), is known to occur in all of the six MRS study areas. Those species that are "listed as threatened or endangered," as they are found in the RI study areas they are noted in Table 2-3. All of the species listed in Table 2-3 are federally-listed as "endangered," with the exception of the Culebrita water-willow, which is listed as a federal "species of concern."

According to the PRDNER, the conservation priority areas for Culebra and associated cays are as follows:

- All of the lagoons on Culebra
- Monte Resaca
- All beaches around Culebra
- The designated critical habitat area for the Virgin Islands Boa
- Flamenco Peninsula
- Puerto del Manglar
- Los Canos
- Punta Soldado
- Bahia (also called "Ensenada") Cementerio
- All cayos and cays around Culebra
- The CNWR
- The Canal Luis Peña Natural Reserve.

The USACE document Standard Operating Procedures for Endangered Species Conservation and their Habitat on Defense Environmental Restoration Program (DERP)-FUDS Project No. I02PR006802.Culebra, Puerto Rico (included as Appendix N of the RI WP) provided a series of Standard Operating Procedures (SOPs) to avoid or minimize impacts to threatened and endangered species during DERP-FUDS work at locations on Culebra Island and adjacent cays and in surrounding waters that serve as habitat for these species. These SOPs "are in accordance with on-going communication with staff from the USFWS, the National Marine Fisheries Service (NMFS) and the PRDNER, as well as pursuant to the Interim Guidelines provided by USFWS to work on lands of CNWR, with the USACE Regulations and Environmental Operating Principles". USA field teams followed all recommended procedures to minimize impacts during the RI field work. The field biologist marked each endangered plant with ribbon to avoid disturbance.

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Table 2-2: Known and potentially occurring federally- and Puerto Rican-listed endangered, threatened, and otherwise protected species on the island of Culebra and outlying Cays, Puerto Rico

Species	Common Name	Taxonomic Group	Status	Habitat
Anolis roosevelti	**Culebra Giant Anole; Lagartijo Gigante de Culebra**	**Lizard**	**FE/CR**	**Mature Forest**
Calyptranthes thomasina	Thomas' Lidflower	Tree-*Myrtaceae*	FE/CR	Forest (Vieques)
Caretta caretta	**Loggerhead Turtle**	**Turtle (Marine)**	**FT**	**Beaches**
Catesbaea melanocarpa	Tropical Lilythorn	Shrub-*Rubiaceae*	FE	Shrub Forest on Limestone (St. Croix)
Chamaecrista glandulosa var. mirabilis	Jamaican Broom	Tree-*Fabaceae*	FE/EN	Forest (Vieques)
Charadrius melodus	**Piping Plover**	**Bird**	**FE/CR**	**Beaches**
Chelonia mydas	**Green Turtle**	**Turtle (Marine)**	**FT/EN**	**Beaches**
Dendrocyna arborea	**West Indian Whistling Duck**	**Bird**	**CR**	**Wetlands**
Dermochelys coriacea	**Leatherback Turtle**	**Turtle (Marine)**	**FE/EN**	**Beaches**
Epicrates monensis grantii	**Virgin Island Tree Boa; Boa Pinta**	Snake	FE/CR	Forest with continuous canopy and abundance of anoles
Eretmochelys imbricata	**Hawksbill Turtle**	**Turtle (Marine)**	**FE/EN**	**Beaches**
Goetzea elegans	Beautiful Goetzea	Tree/Shrub-*Solanaceae*	FE/EN	Forest (Vieques)
Justicia culebritae	**Culebrita Island Water-Willow**	**Subshrub-*Acanthaceae***	**SC**	**Coastal Scrub/Shrub**
Leptocereus grantianus	**Grant's leptocereus**	**Herb-*Cactaceae***	**FE/CR**	**Nonforest and Forest**
Mabuya mabouya sloanei	**Slipperyback Skink; Lucia; St. Lucia**	**Lizard**	**VU**	**Forest**
Pelecanus occidentalis	**Brown Pelican**	**Bird**	**FE/EN**	**Bays and Coastal Areas**
Peperomia wheeleri	**Wheeler's Peperomia**	**Herb-*Piperaceae***	**FE/EN**	**Forest**
Stahlia monosperma*	**Cobana Negra**	**Tree-*Fabaceae***	**FE/VU**	**Margins of Mangrove Swamps**
Sterna antillarum	**Least Tern**	**Bird**	**FE/DD**	**Beaches**
Sterna dougallii	**Roseate Tern**	**Bird**	**FE/VU**	**Nonforested Areas**

Species	Common Name	Taxonomic Group	Status	Habitat
Trachemys stejnegeri	**Jicotea; P. R. Slider**	**Turtle**	**DD**	**Wetlands**
Typhlops granti	**Culebra ciega de Grant; Grant's Blind Worm Snake**	**Snake**	**DD**	**Forest**
Zanthoxylum thomasianum	St. Thomas Prickly-Ash	Shrub-*Rutaceae*	FE/EN	Evergreen Forest on Limestone (St. Thomas)

Source: Compiled by Gaddy, 2011 based on USFWS, 2010b and c

Bold Type-indicates that the species is known to occur on Culebra.

Federal Listings:

FE-federally-listed as endangered;
FT-federally-listed as threatened; **SC**-not officially list, but "species of concern," according to Fish and Wildlife Service;

Puerto Rican Listings:

VU-vulnerable;
EN-en peligro;
CR-en peligro critico;
DD-deficiencia de datos.

*Known to be planted on Culebra; may have escaped into wild areas.

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Table 2-3: Study Areas, habitat/cover types, and endangered species.

Study Area	Name	Habitat/Cover Types	Listed Species present Or Potentially Present *
MRS 06	Artillery Firing Area (Viento Point Area)	Beaches/Shores; Lagoons; Rocky Cliffs; Legume Canopy/Grassland Understory; Low Legume Shrub-Scrub/Cactus	*Dermochelys coriacea* (leatherback turtle); *Eretmochelys imbricata* (hawksbill turtle); *Epicrates monensis grantii* (Virgin Islands tree boa); *Leptocereus grantii* (Grant's leptocereus)
MRS 08	Cayo Norte Impact Area	Beaches/Shores; Lagoons; Rocky Cliffs; Open Grassland; Closed Forest Canopy; Legume Canopy/Grassland Understory	*Dermochelys coriacea* (leatherback turtle); *Eretmochelys imbricata* (hawksbill turtle); *Epicrates monensis grantii* (Virgin Islands tree boa); *Anolis roosevelti* (Culebra giant anole); *Justicia culebritae* (Culebrita water-willow)
MRS 09	Soldado Point Mortar and Bombing Area	Beaches/Shores; Lagoons; Rocky Cliffs; Low Legume Shrub-Scrub/Cactus	*Eretmochelys imbricata* (hawksbill turtle); *Leptocereus grantii* (Grant's leptocereus)
MRS 10	Defensive Firing Area No. 1 (southeast of Dewey)	Beaches/Shores; Rocky Cliffs; Open Grassland; Closed Forest Canopy; Legume Canopy/ Grassland Understory; Low Legume Shrub-Scrub/Cactus	*Eretmochelys imbricata* (hawksbill turtle); *Epicrates monensis grantii* (Virgin Islands tree boa); *Anolis roosevelti* (Culebra giant anole); *Leptocereus grantii* (Grant's leptocereus); *Peperomia wheeleri* (Wheeler's peperomia)
MRS 11	Defensive Firing Area No. 2 (northwest of Dewey)	Beaches/Shores; Lagoons; Rocky Cliffs; Open Grassland; Closed Forest Canopy; Legume Canopy/Grassland Understory	*Eretmochelys imbricata* (hawksbill turtle) *Epicrates monensis grantii* (Virgin Islands tree boa); *Anolis roosevelti* (Culebra giant anole); *Leptocereus grantii* (Grant's leptocereus); *Peperomia wheeleri* (Wheeler's peperomia)
MRS 13	Cayo Luis Peña Impact Area	Beaches/Shores; Lagoons; Rocky Cliffs; Closed Forest Canopy	*Dermochelys coriacea* (leatherback turtle); *Eretmochelys imbricate* (hawksbill turtle); *Epicrates monensis grantii* (Virgin Islands tree boa); *Anolis roosevelti* (Culebra giant anole); *Justicia culebritae* (Culebrita water- willow); *Leptocereus grantii* (Grant's leptocereus); *Peperomia wheeleri* (Wheeler's peperomia).

2.2.9 Cultural and Archeological Resources

According to the National Register Information System (NRIS), National Historic Landmarks (NHL) list, National Heritage Areas (NHA) list, and National Park Service (NPS), there are no registered cultural resources within the Culebra Island MRSs. According to the Puerto Rico

State Historic Preservation Office (SHPO), there are no known architectural resources within the boundary of the MRSs area; however, an architectural survey has not yet been conducted for Culebra.

2.2.10 Demographics

The U.S. Census Bureau's (USCB) Census 2010 provided the general demographics of the Municipality of Culebra summarized in Table 2-4 (USCB, 2011).

Table 2-4: Demographic Summary -- Municipality of Culebra, Puerto Rico

General Characteristics	Number	Percent
Total Population	1,818	
Male	921	50.7
Female	897	49.3
Population Density (persons per square mile)	69.6	
Median Age (years)	39.4	
Under 5 Years	101	5.6
18 Years and Over	1,403	77.2
65 Years and Over	265	14.6
Total Housing Units	1,603	
Occupied Housing Units	749	46.7
Owner-Occupied Housing Units	484	64.6
Renter-Occupied Housing Units	265	35.4
Vacant Housing Units	854	53.3

2.2.11 Current and Future Land Use

2.2.11.1 MRS 06 Artillery Firing Area

MRS 06 is almost entirely privately owned. However, the Commonwealth of PRDNER has jurisdiction over a 1,000 meter wide belt of all Puerto Rico's coastal lands (and additional distances where needed to protect key coastal natural systems), and the territorial waters, including submerged lands beneath them, extending 9 nautical miles offshore. The USFWS is co-manager of the coastal zone as part of the CNWR. This tract contains several residences scattered throughout the MRS. Portions of this tract are currently being developed with others listed for sale for potential development. Site conditions could change in the future with potential impact on land use. Examples might include excessive soil erosion on beaches or streams, or the increase in land development that could reduce distances from the site to inhabited areas or otherwise increase accessibility.

2.2.11.2 MRS 08 Cayo Norte Impact Area

MRS 08 covers all of Cayo Norte, a privately owned island with unrestricted public access. However, to reach the MRS requires a boat; in addition, vegetation and the steep and rugged terrain provide a natural barrier. This combination of needing a boat, and the nature of the island's land features, provides for limiting access to portions of the MRS. One structure identified as a part time residence is present on the south slope (USACE, 1995). The Cayo is owned by an investment group with plans for development. Site conditions could change in the future with potential impact on land use. Examples might include excessive soil erosion on beaches or streams, or the increase in land development that could reduce distances from the site to inhabited areas or otherwise increase accessibility (CRIM, 2011).

2.2.11.3 MRS 09 Soldado Point Mortar And Bombing Area

MRS 09 is managed by the PRDNER and residential development is not currently allowed on the site; however, several shacks and small structures are present in the southeastern portion of the MRS. Several structures are located in the northwestern portion of the MRS. The potential exists for public area structures to be developed at some point in the future. There are no restrictions for using the beach areas or entering the surrounding waters for recreation activities. Site conditions could change in the future with potential impact on land use. Examples might include excessive soil erosion on beaches or streams, or the increase in land development that could reduce distances from the site to inhabited areas or otherwise increase accessibility. Seasonal surf action could cause changes in the bottoms of the surrounding waters (CRIM, 2011).

2.2.11.4 MRS 10 Defensive Firing Area No. 1

MRS 10 is almost entirely privately owned except for municipal lands such as the police and fire stations. Residences are concentrated toward the shoreline along the northern areas of the MRS, and scattered toward the in land in the south eastern areas. Some residential areas have been developed on the hills overlooking the potential mortar impact areas. Site conditions could change in the future with potential impact on land use. Examples might include excessive soil erosion on beaches or streams, or the increase in land development that could reduce distances from the site to inhabited areas or otherwise increase accessibility. Seasonal surf action could cause changes in the bottoms of the surrounding waters. The water area adjacent to this shore is generally not used for recreational activities (CRIM, 2011).

2.2.11.5 MRS 11 Defensive Firing Area No. 2

Most of the southern portion of MRS 11 has been extensively developed for residential use. The areas along the beach and the west side of the MRS are less developed. The land is privately owned with some municipal properties which include a school, hospital, and government buildings. Residential areas have been developed on the hills overlooking the potential mortar impact areas. Development could occur throughout the site. Site conditions could change in the future with potential impact on land use. Examples might include excessive soil erosion on beaches or streams, or the increase in land development that could reduce distances from the site to inhabited areas or otherwise increase accessibility. The immediate offshore waters are part of the Luis Peña Water Refuge (CRIM, 2011).

Residences and other development are concentrated in the southeastern portion of the MRS. A few residences are located along the northern border. A municipal landfill, built in 1984 of approximately 13 acres is located in the northwestern portion of the MRS on the south facing slope. The island airport is located immediately north of the eastern end of the MRS.

2.2.11.6 MRS 13 Cayo Luis Peña Impact Areas

MRS 13 covers all of Cayo Luis Peña. The Cayo is managed by the USFWS and PRDNER as part of the CNWR. Residential areas do not exist on Cayo Luis Peña. USFWS personnel access various areas of the site often, as do boaters who often visit the beach. Heavy vegetation and steep terrain create barriers to access most of the upland areas. Site conditions could change in the future with potential impact on land use. Examples might include excessive soil erosion on beaches or streams, or the increase in land development (public structures) that could reduce distances from the site to inhabited areas or otherwise increase accessibility (CRIM, 2011).

2.3 HISTORICAL INFORMATION

In 1898, the Spanish American War concluded and the Kingdom of Spain ceded all of Puerto Rico to include Culebra and its adjacent cays to the U.S. Shortly after, in 1900, President Theodore Roosevelt placed Culebra under the jurisdiction of the DON. In 1903, the Navy acquired approximately 4,200 acres of land by transfer and purchase; further donations, transfers, and leases between 1939 and 1965 brought the total land acquired to approximately 4,800 acres. Although portions of the site were never formally acquired, military use included the entire Island of Culebra and all surrounding cays. The Navy retained 87.5 acres near Flamenco Point that are not eligible for FUDS. The NWP Target Area was also deemed ineligible for the FUDS program per Public Law 93-166 (Military Construction Authorization Act, 1974). The 2005 revised FDE report states that the site, except for 87.5 acres recently transferred from the control of the Navy and the 408 acres of the NWP (1982 Quit claim Deed), has been determined to be formerly used by the DoD (USACE, 2005).

Although reconnaissance trips, development of a base, and placement of guns began as early as 1902, the first maneuvers at Culebra did not begin until January 1914, with the Marines first Advance Base Expedition establishing several encampments and 3-inch and 5-inch gun batteries at the mouth of Great Harbor. The Marines' use of the island continued over several more decades. In 1922, an exercise was conducted firing 7-inch, 8-inch, 3-inch, 155-millimeter (mm), 75mm, and 37mm guns. In 1924, maneuvers included establishment of ammunitions dumps throughout the island, firing of 75mm and 155mm guns, and mine placement in several water areas around Culebra.

In 1934, the Navy and Marines organized to carry out the first FLEX, Fleet Problem XV. Weapons used during this exercise included .30-caliber machine guns, 3-inch anti-aircraft guns, 6-inch gun batteries, 75mm batteries, and 6-inch naval guns. Six more FLEXs were conducted on Culebra Island between 1935 and 1941. Photographic accounts document Marine landing exercises in 1946 and 1947. Marine training at Culebra is believed to have continued until the late 1950s.

The NWP was used for live gunnery practice between 1936 and January 1, 1972. During this period of time, a total of 750,000 naval rounds had been estimated as being fired. During the period 1942 to 1968, an estimated 320,000 units of air ordnance were fired at the NWP. Eighty

percent of the ammunition was 5-inch caliber. Ten percent was comprised of 3-inch, 6-inch, and 8-inch gun ammunition. The balance included other varieties up to and including 16-inch mortars, and howitzers. (U.S. Navy Memorandum dated June 1973 from Commander in Chief U.S. Atlantic Fleet to Chief of Naval Operations, Subject: Time-Phased Plan for Relocation of Training Activities from the Culebra Complex to the Islands of Desecheo and Monito). Naval exercises included aerial bombardment, submarine torpedo fire, and naval gunfire directed at NWP and many cays. All military use of the island was terminated in 1975. In summary, the Island of Culebra, nearby cays, and surrounding water were used between 1902 and 1975 for training and live fire of bombs, mortars, rockets, torpedoes, projectiles, and small arms.

In 1975, the Navy issued a report of excess for the land associated with the Navy's original 1900 holdings. Beginning in 1978, all of the land acquired by the military on Culebra and the surrounding cays were excessed to the Department of Interior (DOI) or transferred to the government of Puerto Rico by quitclaim deed in 1983.

There is no historical or anecdotal evidence that CWM was ever used within the site.

2.4 PREVIOUS INVESTIGATIONS

The RI at Culebra Island Site Puerto Rico was conducted under the Military Munitions Response Plan (MMRP). The MMRP was created by the Fiscal Year (FY) 2002 National Defense Authorization Act by modifying the DERP to address MEC and MC contamination on inactive, non-operational military ranges. Under the MMRP, the USACE is conducting Environmental Response Activities for the Army. The DERP program investigations that preceded this RI and that are relevant to the MRSs investigated are listed in the following subsections.

2.4.1 1991 – INPR, Culebra, Puerto Rico, Property No. I02PR0068, l May 1991

The original INPR qualified 2,660 acres of Culebra as eligible for consideration under the DERP for FUDS. The INPR, signed on 24 December 1991, established the Culebra Island site as a FUDS, defined a site boundary, and assigned FUDS Project No. I02PR006800. The FDE concluded that "the site, except for 87.5 acres still under control of the Navy, has been determined to be formerly used by the DoD. It is therefore eligible for the DERP." (USACE, 1991)

2.4.2 1995 – ASR, Findings, Ordnance and Explosive Waste, Culebra Island National Wildlife Refuge, Culebra, Puerto Rico, February 1995

The ASR presented the findings of an historical records search and SI for MEC presence in the Culebra Island National Wildlife Refuge. As part of the ASR, a site visit was conducted in October 1994, during which the team identified MD on Cayo Botella, Cayos Geniqui, and Cayo del Agua. In addition, MD was identified on Flamenco Beach, Flamenco Peninsula, and the hillside near Cerro Balcon. The ASR listed several ordnance items verified on site by either EOD personnel or the ASR field team. The ASR covered the entire land area of Culebra Island and the nearby keys, about 7,300 acres of land, and also included 85,200 acres of surrounding water. The report included site history, site descriptions, and real estate ownership information, and confirmed the presence of ordnance based on available records, interviews, and site investigations. (USACE, 1995)

2.4.3 2005 – ASR Supplement, September 2005

In 2004, an ASR supplement was completed by the USACE Rock Island District as an addition to the 1995 ASR. The report provides details of aerial training conducted by the Navy between 1935 and 1975 and identifies the following range areas:

- Water West: Part of this area is included in MRS 12. A local diver reported underwater ordnance in this area. Suspect munitions include Mk II 6-inch HE projectiles.
- Water Center: This area is included in MRS 12. A local diver reported underwater ordnance in this area. Suspect munitions include Mk II 6-inch HE projectiles.
- Water South: This water area includes the small bay north of Soldado Point (part of MRS 09). A local diver reported underwater ordnance in this area. Suspect ordnance includes Mk II 6-inch HE; however, other ordnance types are suspected due to use as 1936 aerial target and 1938 mortar boat firing exercises.
- Rifle Range South: This small arms range is believed to be located on undeveloped land near the southern tip of the island in MRS 09. This range has not been confirmed. The 2005 INPR indicates strafing (.50 caliber) training was conducted in the area. (USACE, 2004a).

2.4.4 2005 – INPR, Original May 1991, Revised July 2005

The original INPR was revised in 2005, clarifying the military use of the Island of Culebra and divided the original site, Property No I02PR0068, into 14 separate projects. One hazardous and toxic waste (HTW) project was identified and assigned the number 00, and 13 MMRP project areas were identified and assigned Risk Assessment Code (RAC) scores. MRS 01 was not defined (USACE, 2005a).

The following MMRP projects and RAC scores were listed:

- MRS 02 – Culebra and Cays, RAC 1
- MRS 03 – Flamenco Bay Water Area, RAC 1
- MRS 04 – Flamenco Lagoon Maneuver Area, RAC 1
- MRS 05 – Mortar and Combat Range Area, RAC 1
- MRS 06 – Artillery Firing Area, RAC 3
- MRS 07 – Culebrita Artillery Impact Area, RAC 1
- MRS 08 – Cayo Norte Impact Area, RAC 3
- MRS 09 – Soldado Point Mortar and Bombing Area, RAC 2
- MRS 10 – Defensive Firing Area No. 1, RAC 2
- MRS 11 – Defensive Firing Area No. 2, RAC 1
- MRS 12 – Luis Peña Channel Water Areas, RAC 1
- MRS 13 – Cayo Luis Peña Impact Area, RAC 1
- MRS 14 – Airfield and Camp Area, RAC 3

The HTW Project 00, also as known as The Former Lower Camp Debris Site, encompasses a 40,000-square foot section (100 feet by 400 feet) of marine wetland located along the eastern

shoreline of Ensenada del Cementerio (Figure 1-2). The surface and groundwater drains directly into Ensenada Honda and does not directly affect the MRSs covered by this project. 2005 – Supplemental ASR, Culebra, Puerto Rico, September 2005

USACE St. Louis District prepared the Supplemental ASR in 2005 as an addition to the 1995 ASR. The Supplemental ASR is the source of most of the historical information pertaining to site operations and identified the key areas of focus for the subsequent SI. This document provided a detailed summary of military activities conducted on Culebra Island and the surrounding cays. The document summarized planned and/or executed maneuvers and training conducted at the site, including specific time periods, locations, and munitions used. (USACE, 2005b)

2.4.5 2007-SI Report, Culebra Island Site, Puerto Rico, FUDS Project No. I02PR006802 through I02PR006814, September 2007

Parsons Infrastructure and Technology Group (Parsons) completed an SI of the Island and published a Final SI Report in September 2007. The fieldwork included approximately 50 miles of Qualitative Reconnaissance, and the collection of 27 soil and five sediment samples. The fully validated samples were analyzed for MC metals and explosive compounds. Three of the soil samples were collected to serve as ambient data. Table 2-5 provides the transect acreage investigated during the SI by MRS. Appendix A: Figures A31 through A36 demonstrate the full investigation covereage for each MRS when both the RI and SI are combined substantially increasing the investigation acres for Culebra MRSs.

Table 2-5: SI Transect Acreage

MRS Description	Qualitative Reconnaissance Transect Acres
MRS 02 – Northwest Peninsula, Cerro Balcon, and Adjacent Cayos	1.65 acres (Adjacent Cayos acreage provided)
MRS 04 - Flamenco Lagoon Maneuver Area	1.42 acres
MRS 05 - Mortar and Combat Range Area	3.56 acres
MRS 06 - Artillery Firing Area	1.46 acres
MRS 07 - Culebita Artillery Impact Area	1.26 acres
MRS 08 - Cayo Norte Impact Area	.71 acres
MRS 09 - Soldado Point Mortar and Bombing Area	.08 acres
MRS 10 - Defensive Firing Area No. 1	.68 acres
MRS 11 - Defensive Firing Area No. 2	1.38 acres
MRS 13 - Luis Peña Impact Area	.82 acres
MRS 14 - Airport and Camp Area	.85 acres

The following is the SI Summary of Findings and Conclusions (Parsons, 2007):

SI Findings and Conclusions Regarding Potential MEC

- Culebra Island and the surrounding cays and cayos were used for aerial bombing, maneuvers, artillery firing, and amphibious training by the U.S. Navy and the U.S. Marine Corps between 1902 and 1975. Reported munitions included various projectiles, rockets, mortars, HE bombs, and practice bombs. During the SI, the field team did not observe any MEC; however, they identified MD in six of the MRSs.

- The SI concluded that the potential for MEC to pose a human health risk existed within 12 of the 13 MRSs, but that there was no evidence to indicate that MRS 14 had potential MEC contamination. Parsons further concluded that although there was potential for MEC to pose a risk at the Culebra Island sites, since the field team did not identify an imminent threat to the public, a TCRA was not necessary. However, due to the presence of MD and MEC at several areas within the site, Parsons recommended these sites proceed to the RI/FS. (Parsons, 2007)

SI Findings and Conclusions Regarding MC

- Assessment of the Culebra Island FUDS site included evaluating site-specific conditions that could impact the potential for complete exposure pathways to human and ecological receptors at the site. The SI evaluation included performing approximately 50 miles of walked QR and collecting 32 samples. The samples were analyzed for MC, including explosives and metals, and analytical results were compared to the following three criteria to determine the need to perform a SLRA for each particular analyte:
    - Was the analyte a potential constituent of munitions known or suspected of being used on site;
    - Was the analyte considered a hazardous substance listed in 40 CFR Part 302, Table 302.4 of CERCLA;
    - Was the analyte detected above the maximum ambient concentration.
- The list of constituents for munitions known or suspected was developed in the SI and updated for the RI; Appendix N of this report contains a copy of this list.
- There is no evidence the lagoons of the island were used for target practice. No explosive compounds were detected in any of the soil or sediment samples; metals were detected in all of the MRSs. SLRAs were performed for each analyte that met all three criteria. The SLRAs compared MC detections in soil and sediment to USEPA Region 9 residential soil preliminary remediation goals (PRGs) for human health risk and USEPA Region 4 ecological screening values (ESVs) for ecological risk. All detected metals retained for SLRA were found to be below human health screening levels. Metals were detected above ecological screening values at MRSs 02, 04 through 10, 13, and 14.
- The SI evaluated the potential for complete MC exposure pathways to human and ecological receptors through soil, groundwater, surface water, and air. There are no groundwater receptor exposure points, and the climate on the island is too wet and vegetated to generate significant quantities of fugitive dust; therefore, the groundwater and air pathways are considered incomplete for human or ecological receptors at all MRSs. Soil and surface water pathways may be complete for human and/or ecological receptors on several MRSs.
- The SI recommended further evaluation of MC at MRSs 02, 04-10, and 13 to evaluate potential ecological risk.

CHAPTER 3. PROJECT REMEDIAL RESPONSE OBJECTIVES

This RI project was conducted in accordance with the objectives and goals established by stakeholders during TPP as summarized in the Final TPP Memorandum (Appendix F). The primary objective for the RI was to determine the nature and extent of MEC and MC within the terrestrial boundaries of MRS 06, MRS 08, MRS 09, MRS 10, MRS 11, and MRS 13 on Culebra Island.

The TPP team agreed that the RI data collection would focus on geophysical (transects and grids) and intrusive investigation of grids in the upland areas, analog intrusive investigations along accessible beaches and in-use trails on MRS 13, and collection of environmental samples at locations in and around areas that represent the highest likelihood for MC contamination i.e., where MEC or MD is present, at demolition sites, and where there is evidence of low order detonations.

3.1 CSM AND PROJECT APPROACH

CSMs can help identify risks to human health and the environment by identifying complete exposure pathways between physical media affected by site-related contamination and potential human or ecological receptors. During the SI at Culebra (Parsons, 2007), the site was evaluated as 14 MRSs. The evaluation of potential MEC exposure concluded that, based on the limited scope of the SI, the MEC exposure pathway was potentially complete for all six MRSs evaluated during this RI. The MRS boundaries, which were based on former suspected military use and current land use, provided the basis for the pre-RI CSM presented in the Final TPP Memo (Appendix F) and RI WP. Based on the results of the SI, the pre-RI CSM identified a potentially complete MEC exposure pathway for human receptors in MRSs 06, 08, 09, 10, 11, and 13. Pre-RI CSM Diagrams are provided as Figures 3-1 through 3-6. The objective of the RI field activities was to adequately characterize each area to determine whether an unacceptable hazard exists, and to support evaluating and developing effective remedial alternatives. DGM, intrusive investigation of anomalies, analog mag-and-dig investigations, and MC sampling were the basis of the RI characterization. In addition to collecting samples at specified locations in some MRSs, MC sampling would also be done in association with MEC and MD with residual explosives. One consequence could be that some MRSs would not have MC samples collected. The following sections provide additional details regarding the CSM and project approach for each MRS. Based on the results of the contaminant characterization conducted as part of this RI, a revised CSM is presented and discussed in Chapter 5.

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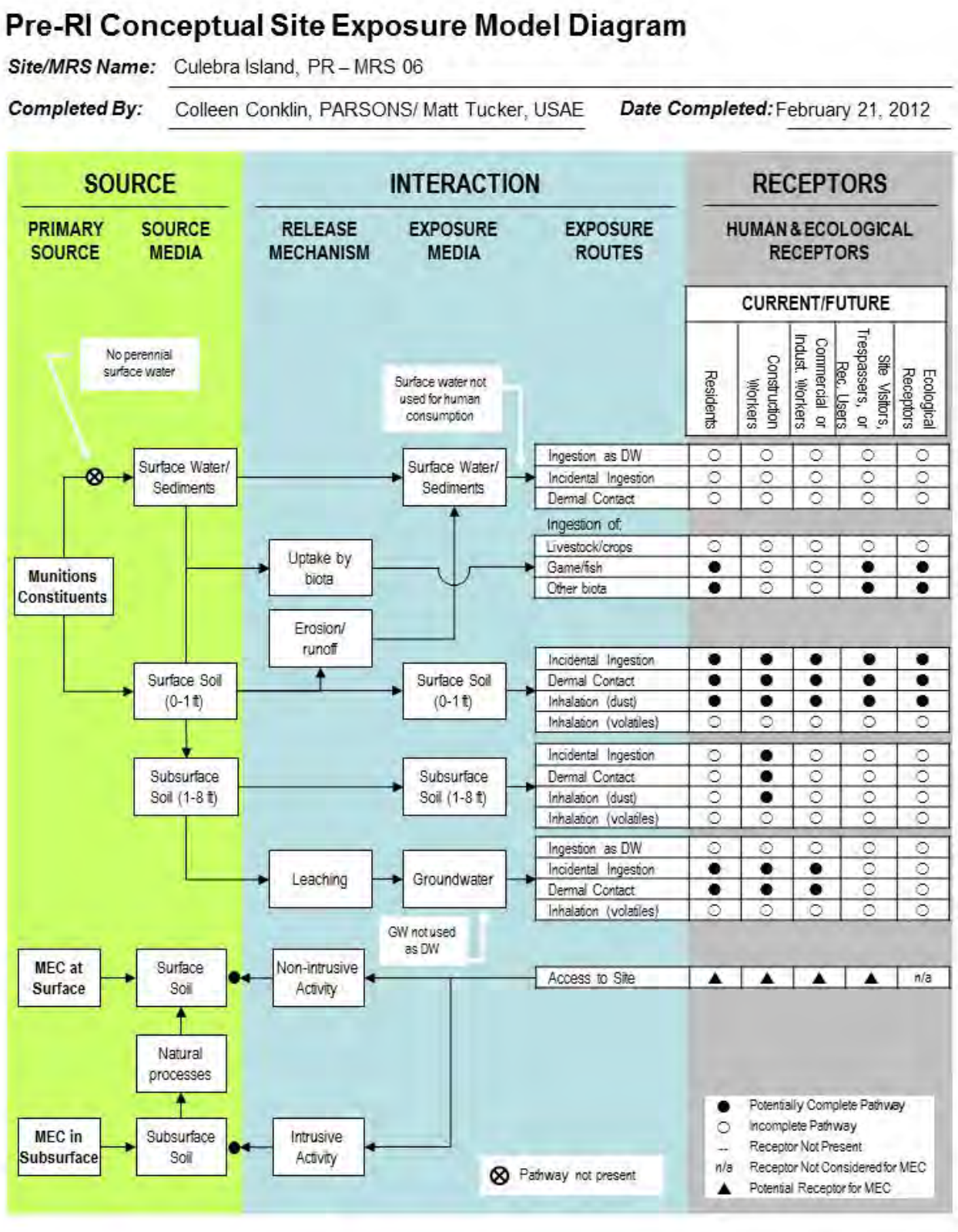

Figure 3-1: MRS 06 Pre RI CSM

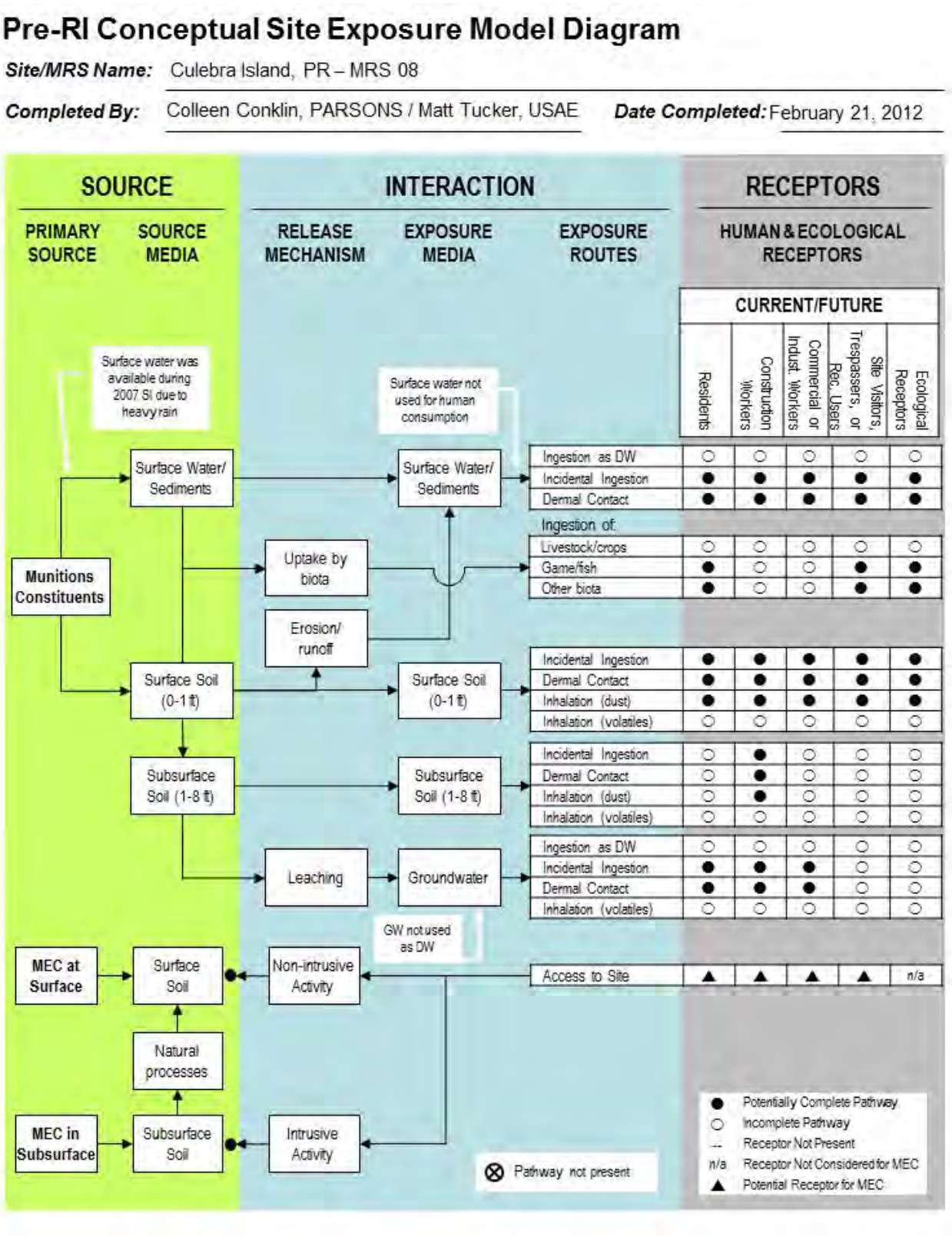

Figure 3-2: MRS 08 Pre-RI CSM

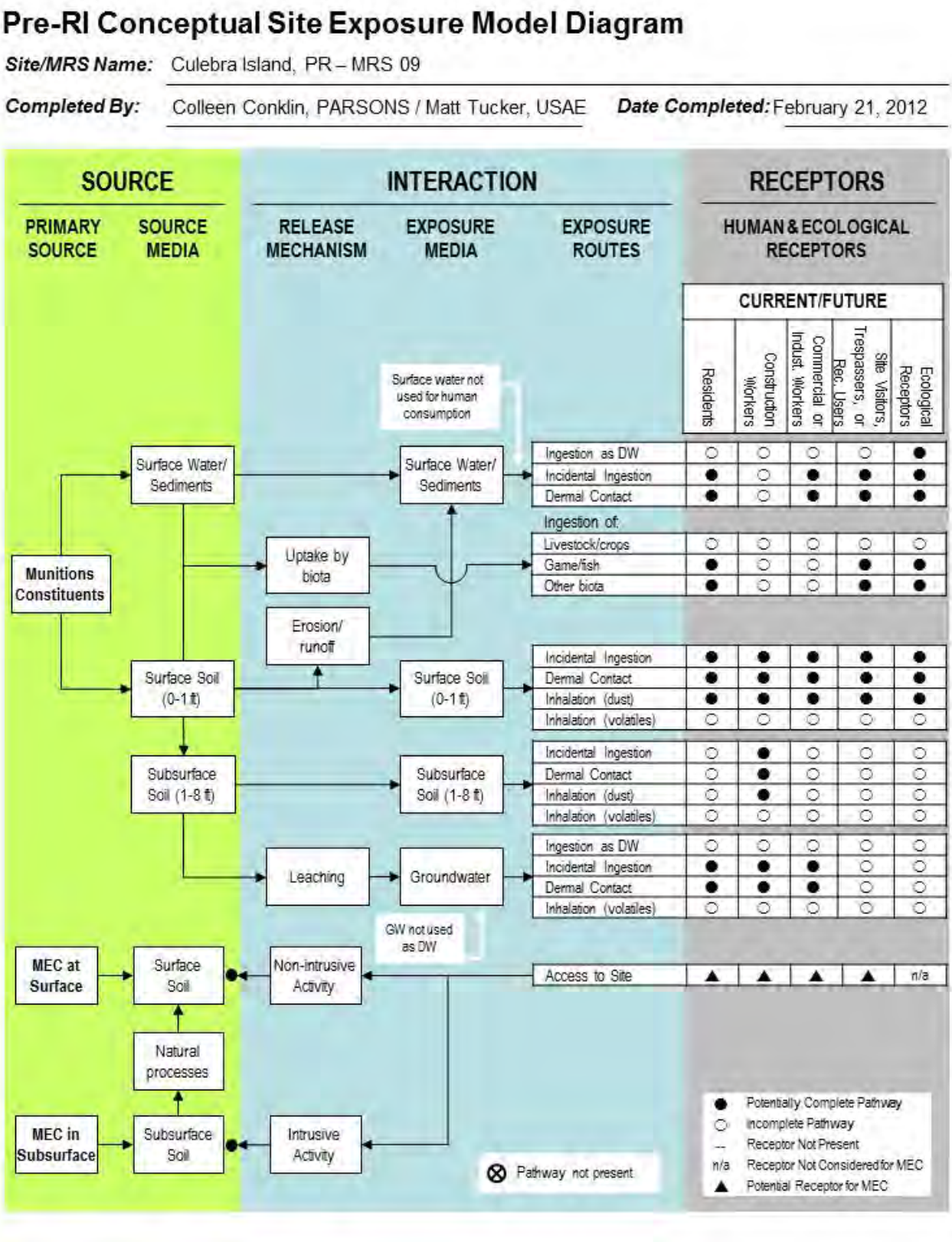

Figure 3-3: MRS 09 Pre-RI CSM

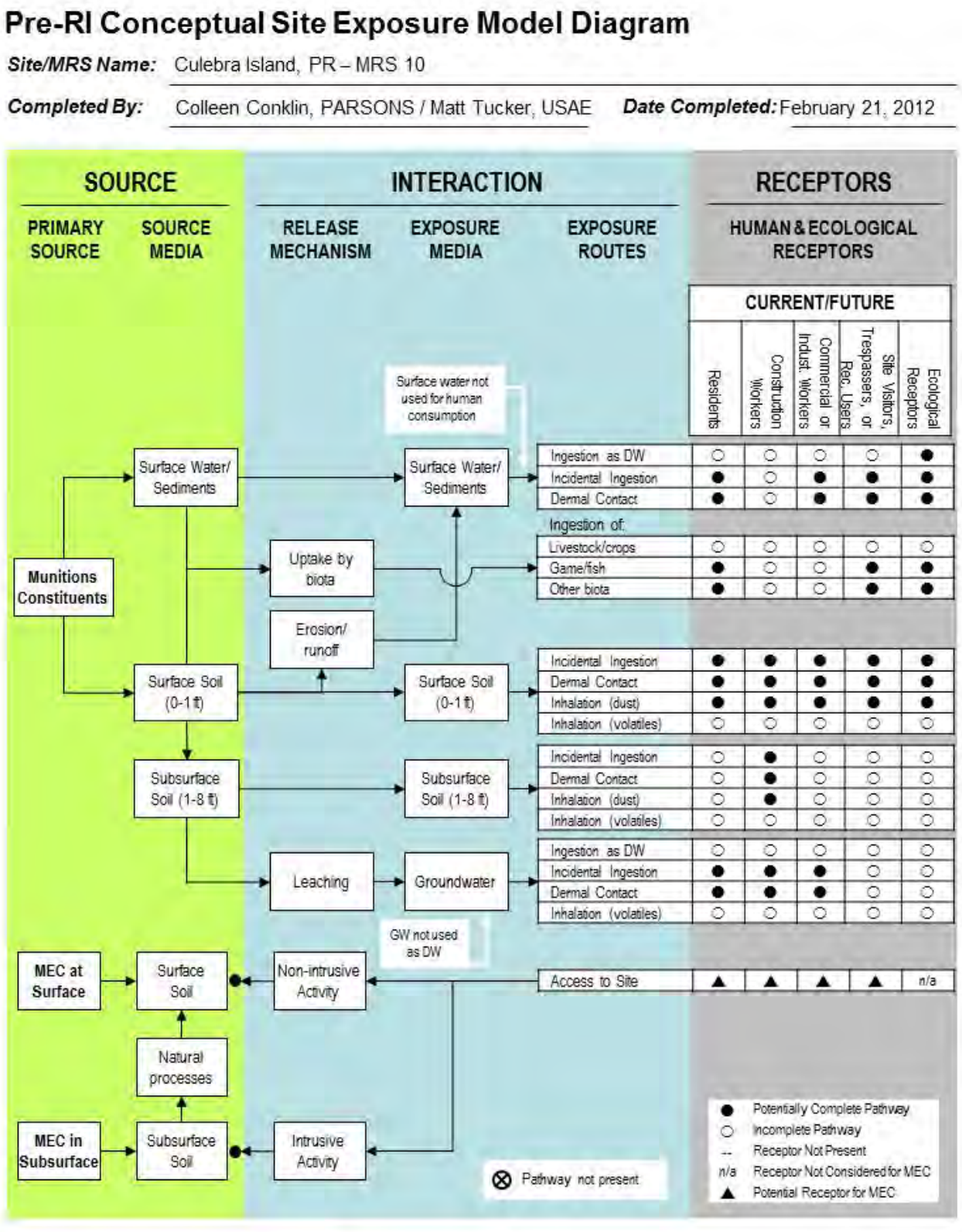

Figure 3-4: MRS 10 Pre-RI CSM

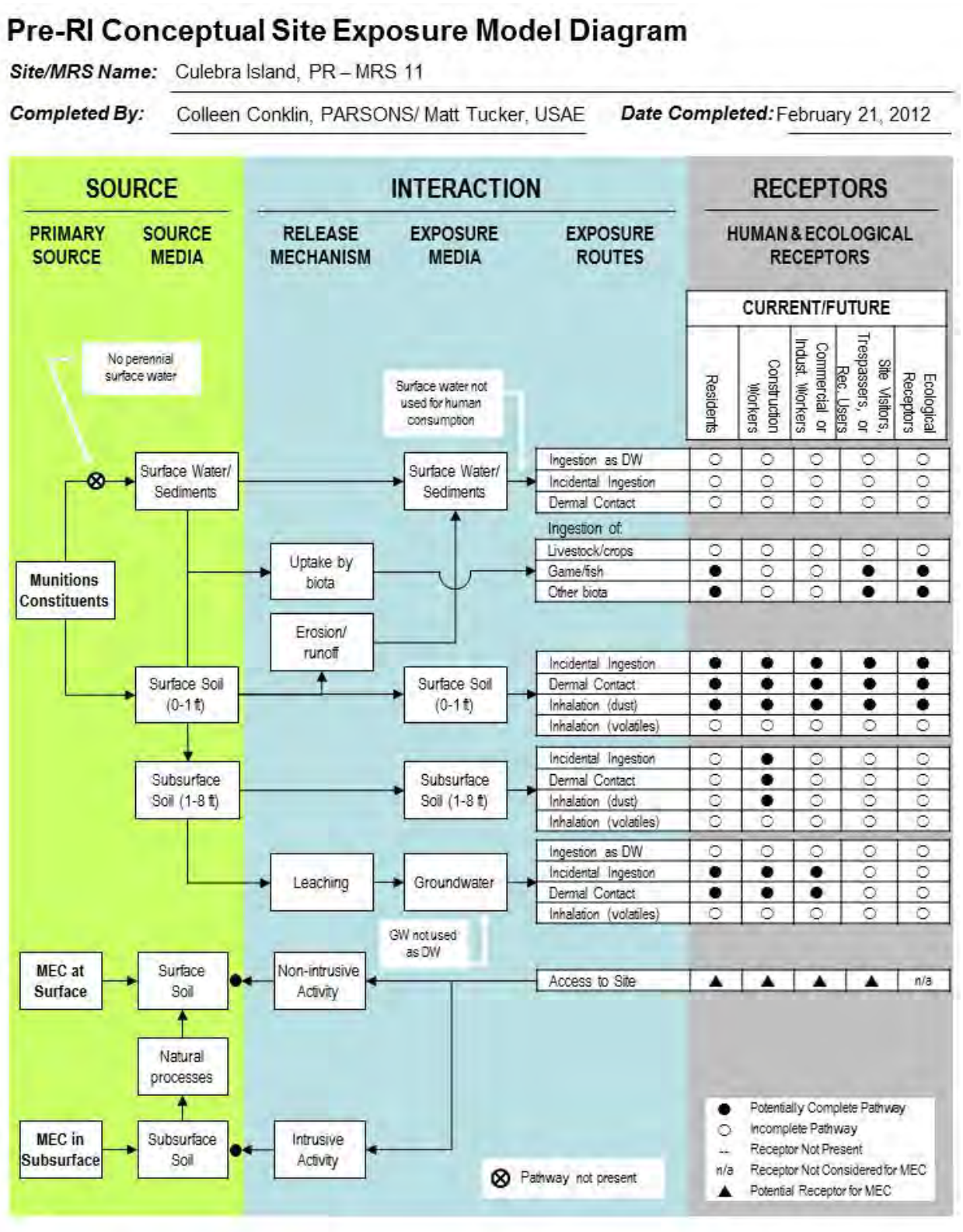

Figure 3-5: MRS 11 Pre-RI CSM

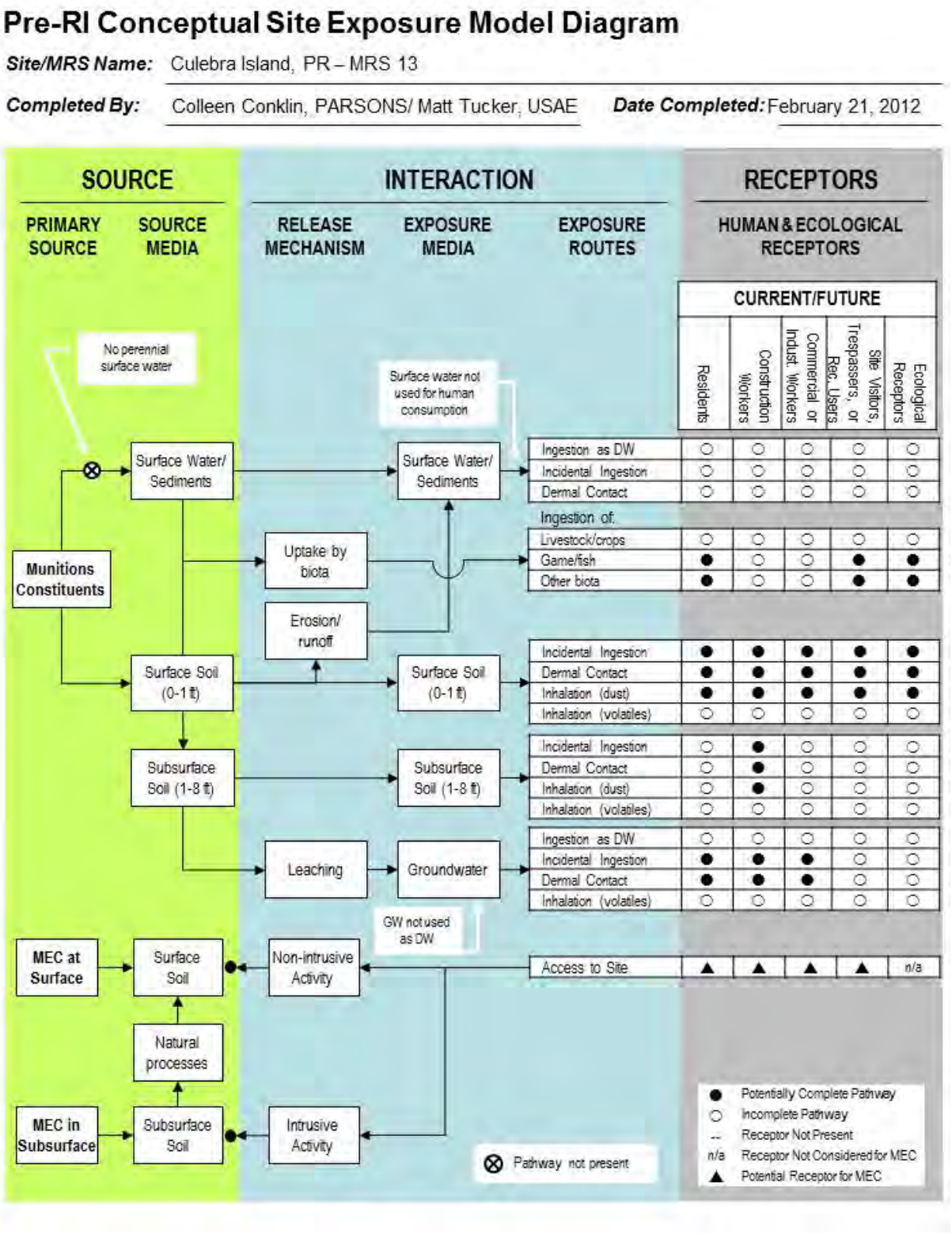

Figure 3-6: MRS 13 Pre-RI CSM

3.1.1 MRS 06 Artillery Firing Area

The Pre-RI CSM identified a potentially complete MEC exposure pathway for human receptors due to the potential presence of surface and subsurface MEC from military training in the area. Exposure pathways related to MC were identified as potentially complete for human and ecological receptors; therefore, an evaluation of MC was included in the RI for both human and ecological receptors. There is no evidence the lagoons in the MRS were used for target practice.

MRS 06 is easily accessible to improved areas such as residences and public beaches (Larga and Zoni Beaches). A majority of MRS 06 consists of heavily vegetated and steep terrain. Some areas can be difficult for human receptors to access. Based on the current and projected land use for additional residential development, access to undeveloped areas may increase.

The RI was designed to assess the presence / nature and extent of surface and subsurface MEC within MRS 06. The project approach included DGM and intrusive investigation of identified anomalies within the upland areas, analog mag-and-dig investigations within the beach areas, and MC sampling at locations where MEC or MD are identified.

3.1.2 MRS 08 Cayo Norte Impact Area

The Pre-RI CSM identified a potentially complete MEC exposure pathway for human receptors due to the potential presence of surface and subsurface MEC. Exposure pathways related to MC were identified as potentially complete for human and ecological receptors; therefore, an evaluation of MC was included in the RI for both human and ecological receptors.

MRS 08 is a privately owned island and is accessible only by boat. MRS 08 contains very few improved areas such as dirt roads/paths and a beach area. Given that all beaches in the Commonwealth of Puerto Rico allow public access, additional human receptors are able to access MRS 08. Based on the current and projected land use, a low amount of private residential development may occur in the future. Per the current land owner, an estimated 10 homes may be constructed on Cayo Norte. A water source will be provided through the installation of a well near the shoreline and a reverse osmosis process will be used to clean/purify the water. This water source will be supplemented by the capture of rainwater. The houses, if or when they are constructed, will be built on the rock surface with some intrusive work to support the foundations.

The RI was designed to assess the presence/nature and extent of surface and subsurface MEC within MRS 08. The project approach included DGM and intrusive investigation of identified anomalies within the upland areas, analog mag-and-dig investigations within the beach areas, and MC sampling at locations where MEC or MD are identified.

3.1.3 MRS 09 Soldado Point Mortar and Bombing Area

The Pre-RI CSM identified a complete MEC exposure pathway for human receptors due to the potential presence of surface and subsurface MEC. Exposure pathways related to MC were identified as potentially complete for human and ecological receptors; therefore, an evaluation of MC was included in the RI for both human and ecological receptors.

A majority of MRS 09 is administered by the PRDNER. A small amount of MRS 09 contains four residences and a portion of a hotel resort (northeast corner of MRS). Aside from this area MRS 09 contains no official improved areas. Although the current land use for the PRDNER

portion of MRS 09 does not allow for development, some unauthorized developments (squatter houses) have been constructed within Sueño Cove. There is currently no controlled access to the PRDNER portion of MRS 09. This portion is easily accessible by a partially paved road through the center of the MRS. The paved portion stops at the top of Ensenada Dakity; however, an unimproved road continues down into Sueño Cove and the beach areas. Based on the current and projected land use there are no plans to develop the PRDNER portion

The RI was designed to assess the presence /nature and extent of surface and subsurface MEC within MRS 09. The project approach included DGM and intrusive investigation of identified anomalies within the upland areas, analog mag-and-dig investigations within the beach areas, and MC sampling at locations where MEC or MD are identified. There is no evidence that the interior acres or the lagoons in the MRS were used for target practice.

3.1.4 MRS 10 Defensive Firing Area No. 1

The Pre-RI CSM identified a potentially complete MEC exposure pathway for human receptors due to the potential presence of surface and subsurface MEC. Exposure pathways related to MC were identified as potentially complete for human and ecological receptors; therefore, an evaluation of MC was included in the RI for both human and ecological receptors.

MRS 10 is easily accessible to improved areas such as residential and commercial properties. The town of Dewey extends into the northern portion of the MRS. The western portion of MRS 10 consists of heavily vegetated and steep terrain that is currently undeveloped. This area can be difficult for human receptors to access. Based on the current and projected land use for additional residential development, access to undeveloped areas may increase.

The RI was designed to assess the presence /nature and extent of surface and subsurface MEC within MRS 10. The project approach included DGM and intrusive investigation of identified anomalies within the upland areas, analog mag-and-dig investigations within the beach areas, and MC sampling at locations where MEC or MD are identified.

3.1.5 MRS 11 Defensive Firing Area No. 2

The Pre-RI CSM identified a complete MEC exposure pathway for human receptors due to the potential presence of surface and subsurface MEC. Exposure pathways related to MC were identified as potentially complete for human and ecological receptors; therefore, an evaluation of MC was included in the RI for both human and ecological receptors.

MRS 11 is easily accessible to improved areas such as residential and commercial properties. The eastern portion of MRS 11 contains the majority of residential and commercial properties in Culebra. The northern portion of MRS 11 contains the municipal landfill and is adjacent to the NWP Bombardment area. The western portion of MRS 11 consists of heavily vegetated and steep terrain which contains limited residential and public beach areas (Tamarindo and Melones beaches). Portions of this MRS can be difficult for human receptors to access. MRS 11 contains six public beach areas that are frequented by residents and tourists. Based on the current and projected land use for additional residential and commercial development, access to undeveloped areas may increase.

The RI was designed to assess the presence /nature and extent of surface and subsurface MEC within MRS 11. The project approach included DGM and intrusive investigation of identified

anomalies within the upland areas, analog mag-and-dig investigations within the beach areas, and MC sampling at locations where MEC or MD are identified. There is no evidence the lagoon in the MRS was used for target practice.

3.1.6 MRS 13 Cayo Luis Peña Impact Areas

The Pre-RI CSM identified a potentially complete exposure pathway for human receptors due to the potential presence of surface and subsurface MEC. Exposure pathways related to MC were identified as potentially complete for human and ecological receptors; therefore, an evaluation of MC was included in the RI for both human and ecological receptors.

MRS 13 is an island and is accessible only by boat. MRS 13 is administered by USFWS and is part of the Culebra Wildlife Refuge. MRS 13 contains very few improved areas consisting of a single road/path that leads up to the old helipad. MRS 13 contains established beach areas. Given that all beaches in the Commonwealth of Puerto Rico allow public access, additional human receptors are able to access MRS 13. Current and projected land use is to remain as a wildlife refuge.

The RI was designed to assess the presence /nature and extent of surface and subsurface MEC within MRS 13. The project approach included analog instrument assisted reconnaissance along the main trail to the helipad area, analog mag-and-dig investigations within the beach areas, and MC sampling at locations where MEC or MD are identified.

3.2 PRELIMINARY REMEDIATION GOALS

PRGs are both site- and contaminant-specific and define the conditions considered by stakeholders to be protective of human health and the environment. There may be PRGs for MEC and MC at each site evaluated during a RI. As with the CSM, PRGs may be reevaluated and refined throughout the RI process as new information becomes available.

To develop the PRGs for MEC and MC, the Culebra Island MRSs required sufficient characterization of the presence of MEC and MC. MEC/MD were characterized in these areas based on DGM and intrusive data collected during the RI. Environmental samples were collected and analyzed in order to characterize MC contamination.

3.2.1 Preliminary Remediation Goal for MEC

The PRG for all six of the Culebra Island MRSs is to ensure that any identified unacceptable MEC hazard will be addressed to minimize or mitigate the hazard to a negligible/unlikely probability of encounter.

3.2.2 Preliminary Remediation Goal for MC

The PRG for MC at all six of the Culebra Island MRSs is to ensure that identified unacceptable levels of MC risk will be addressed to minimize or mitigate to an acceptable level.

3.3 PRELIMINARY IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENT (ARAR) AND TBC INFORMATION

Response actions under FUDS must identify and attain or formally waive ARARs. These are federal environmental or state environmental or facility siting laws. At the initiation of the RI,

the preliminary identification of chemical-specific and location-specific ARARs is performed. ARARs may dictate minimum cleanup standards as well as influence the selection of the remedial alternative for the site. The initial list of ARARs developed in the RI phase will be modified as site understanding expands during the characterization and development of alternatives phases. ARARs will be carefully evaluated based on the standard and the specific applicability of that standard, and on a site-specific basis. When ARARs do not exist for a particular chemical or remedial activity, other criteria, advisories, and guidance referred to as To Be Considered (TBC) are useful in designing and selecting a remedial alternative. A list of ARARs and TBCs that are specific to the Culebra Island MRSs are included in Table 3-1.

Table 3-1: Potential ARARs and TBCs for the Culebra Island MRSs

Location-Specific ARARs	
The Endangered Species Act (USC) Title 16 chapter 35§1536 (a)(2)	Protects federal listed species located within Culebra Island MRSs by regulating takes of listed species.
Action-Specific ARARs	
RCRA Subpart X 40CFR Part 264	Establishes Solid Waste Management rules related to explosive waste management during clean up actions
The Migratory Bird Treaty Act; 16 USC § 704	Establishes rules for preventing take of listed migratory bird species
Action-Specific TBCs	
Local Conservation Goals	Possible TBC for limiting vegetation removal. Specific citations to be added to the FS.
U.S. Environmental Protection Agency (USEPA) PSVs	Establishes screening levels for specific contaminants of concern.
PREQB Water Quality Standards (WQS) and USEPA Preliminary Screening Levels	Establishes screening levels for specific contaminants of concern.

As the RI/FS process continues, the list of ARARs and TBCs are updated, particularly as guidance is issued by state and federal agencies. ARARs and TBCs were used as a guide to establish the appropriate extent of site cleanup; to aid in scoping, formulating, and selecting proposed treatment technologies; and to govern the implementation and operation of the selected remedial alternative. As the ARARs are further developed and refined as part of the FS, primary consideration will be given to remedial alternatives that attain or exceed the requirements of the identified ARARs and TBCs. Throughout the RI/FS phase, ARARs and TBCs are identified and evaluated by taking into account the following:

- Contaminants suspected or identified to be at the site
- Chemical analysis performed, or scheduled to be performed
- Types of media (soil, surface water, and sediment)
- Geology and other site characteristics
- Use of site resources and media
- Potential contaminant transport mechanisms

- Purpose and application of potential ARARs and TBCs
- Remedial alternatives considered for site cleanup.

Chemical-specific ARARs are promulgated health-based or risk-based numerical values that establish the acceptable amount or concentration of a chemical that may remain in, or be discharged to, the ambient environment. Risk-based screening levels [e.g., USEPA Regional Screening Levels (RSLs)] are not chemical-specific ARARs because they are not promulgated; however, risk-based screening levels can be considered chemical-specific TBCs. The PREQB WQS and USEPA RSLs, May 2012 (Soil, Surface Water, and Sediment) and November 2013 (Groundwater), have been identified as chemical-specific TBCs for MC.

Location-specific ARARs generally are restrictions placed on the concentration of hazardous substance or the conduct of activities solely because they are in special locations. An action in these locations may cause irreparable harm, loss, or destruction of ecological resources. The Endangered Species Act [USC Title 16 chapter 35§1536 (a)(2)] has been identified as location-specific ARARs.

Action-specific ARARs are usually technology- or activity-based requirements or limitations placed on actions taken with respect to remedial/removal actions, or requirements to conduct certain actions to address particular circumstances at a site. RCRA Subpart X (40 CFR Part 264) and the Migratory Bird Treaty Act; 16 USC 704 are considered to be action-specific ARARs for the Culebra Island MRSs. In addition, a limitation for vegetation removal in support of removal actions may be included as a TBC for all MRSs.

3.4 SUMMARY OF INSTITUTIONAL ANALYSIS

The Institutional Analysis (Appendix D: Institutional Analysis) is prepared to support the development of institutional control strategies and plans of action as a munitions response alternative. These strategies rely on existing powers and authorities of government agencies to protect the public at large from MEC risks.

A review of government institutions and private entities that exercise jurisdiction and ownership of the areas indicated that the property encompassing the Culebra Island MRSs was under the varying levels of jurisdiction of several agencies including the Municipality of Culebra; the Commonwealth of Puerto Rico (PREQB and PRDNER); and the United States government agencies (USFWS and USACE). The role of each of these agencies is summarized below.

Institutional controls on privately owned land will only be effective if property owners are willing to participate and implement designed controls on their property.

3.4.1 Municipality of Culebra

The Culebra Island MRSs lie entirely within the island of Culebra, which is locally governed by a municipality. The municipality oversees building permits, fire, police, and emergency management responsibilities, and land use controls over municipal properties. The municipality has numerous joint, mutual aid and planning agreements and other relationships with all levels of government and can assist and work with the USACE in developing land use controls related to the Culebra Island MRSs. The Municipality has also provided a member to serve on the Restoration Advisory Board (RAB) for Culebra.

3.4.2 Commonwealth of Puerto Rico

3.4.2.1 PRDNER

PRDNER serves as the Commonwealth's lead natural resource conservation agency. PRDNER is responsible for managing lands and waterways under its jurisdiction and enforcing compliance with the Commonwealth's natural resource regulations. Representatives from PRDNER have participated as part of the TPP including attending meetings and reviewing and providing comments on project documents. The PRDNER also provides a member to serve on the Culebra RAB.

3.4.2.2 Puerto Rico Environmental Quality Board (PREQB)

The PREQB is the principal environmental protection regulator in Puerto Rico. Representatives from PREQB have participated as part of the TPP including attending meetings and reviewing and providing comments on project documents. The PREQB also provides a member to serve on the Culebra RAB.

3.4.3 United States Government Agencies

3.4.3.1 USFWS

The mission of the USFWS is to work with others to conserve, protect and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people. In Culebra USFWS is responsible for managing the CNWR, which is located in various portions of Culebra. USFWS is also responsible for managing other lands under its jurisdiction and enforcing compliance with federal regulations. Representatives from USFWS have participated as part of the TPP including attending meetings and reviewing and providing comments on project documents. USFWS also provides members to serve on the Culebra RAB.

3.4.3.2 U.S. Army Corps of Engineers

USACE is the lifecycle Project Manager for the Culebra Island FUDS program. USACE has no jurisdiction or authority in Culebra; however, USACE provided project coordination responsibilities including review of project plans and documents, obtaining rights-of-entry to properties in the work area, working with the news media and the public, and coordinating with federal, state, and local agencies on issues pertaining to implementation of this project and protection of ecological and cultural resources. Other responsibilities include coordinating any necessary evacuations, providing proper notifications to the PRDNER, notifying the National Response Center and state officials in the event of a release or spill, and signing the hazardous waste manifests as the generator of any hazardous waste.

The DERP is the primary funding source, and USACE is the executor for conducting CERCLA projects on Culebra FUDS. The USACE is the implementing agency for execution of this project, providing technical expertise for MEC and MC activities, and serving as the technical manager for conducting the RI/FS. USACE responsibilities include procurement and direction of the prime contractor (USA Environmental, Inc.) and supporting agencies, and the coordination of document reviews and approvals. USACE also provides the on-site UXO-Qualified Safety Specialist.

3.5 DATA NEEDS AND DQO

3.5.1 Data Needs

Previous studies of the Culebra Island MRSs, including the SI Report (Parsons, 2007), the ASR (USACE, 1995), and the ASR Supplement (USACE, 2005), were reviewed prior to developing the RI/FS WP. Although no MEC was found during the SI fieldwork, an RI/FS was recommended based on the presence of MD on the surface and historical records. The data needs for the RI/FS project (i.e., assessment of MEC and MC throughout the MRSs) were reviewed by the TPP Team. DQOs associated with the data to be collected during the RI were developed by the TPP Team and included in the WP.

Several suggestions and requests by the TPP Team affected the type of data to be collected as part of the RI. During the TPP, stakeholders agreed to the following:

- To conduct geophysical investigations in the upland portions of each MRSs (excluding MRS 13) along transects and grids. Vegetation removal would be required prior to conducting DGM surveys. Endangered species mitigation measures (SOPs) would need to be employed while completing vegetation removal. DGM data would be initially collected along transects with an EM61-MK2. DGM transect anomalies within each MRS would be subsequently processed to produce an anomaly density map to guide grid placement for characterizing high anomaly density areas.
- Intrusive investigations would be conducted within upland area grids and within beach areas of each MRS, with the exception of MRS 13, where only beach digs were completed. Note: Per a USFWS request, the upland area grids were replaced with analog transect investigation of established trails as a less destructive method of investigation to the environment. The MRS 13 investigation was supplemented with visual surface reconnaissance from a 2009 post award site visit.
- The TPP agreed on the recommended laboratory analyses to be conducted on the environmental samples collected. Metals (minus essential nutrients) were to be analyzed via method SW6010B and SW6020A (mercury - SW7470A/SW7471A) and explosives by method SW8330A. Methods for groundwater analysis included: Explosives-SW8330B, Metals-SW7470A, Ammonia Picrate-SW8321A, and Perchlorate-SW6850. Other groundwater analyses EPA Methods: Chloride-E300.0 and Nitrate/Nitrite as Nitrogen-E353.2. For samples that are designed to investigate the extent of a previously detected constituent, the analyses would be limited to that constituent.

3.5.2 DQOs

DQOs are qualitative and quantitative criteria used to guide sample collection and analysis activities. The DQOs for this RI/FS project were developed prior to conducting investigative activities to ensure that the data generated during the execution of the analytical program are of appropriate quality to support the anticipated end use of the data. The DQOs follow the seven step process established in the USEPA QA/G-4HW Guidance. DQOs seek to ensure that the right type, amount, and quality of data are collected to accomplish the objectives of the project. Below are the seven DQO steps from the USEPA guidance.

1. State the Problem
2. Identify the Decision

3. Identify the Inputs to the Decision
4. Define the Study Boundaries
5. Develop a Decision Rule
6. Specify Limits of the Decision Errors
7. Optimize the Design for Obtaining Data

Table 3-2 reflects the DQOs for the RI data collection activities. These DQOs were taken from the TPP Meetings and then applied to the Final RI WP approved by the USACE.

Table 3-2: Project DQOs

Step	Culebra Island MRSs (Terrestrial)
1. State Problem(s)	• Define the nature and extent of MEC contamination relative to future land use, potential receptors, and accessibility within MRSs • Define the nature and extent of MC contamination relative to future land use, potential receptors, and accessibility within MRSs
2. Identify the Decision	• Determine where *surface and subsurface* MEC contamination poses an unacceptable risk to human health and the environment and requires further consideration or a response action, or recommended that no further investigation is necessary • Determine where surface soil, subsurface soil, surface water, groundwater and sediment MC contamination poses an unacceptable risk to human health and the environment and requires further consideration or a response action, or recommended that no further investigation is necessary
3. Identify the Inputs	• Future Land Use, Potential Receptors, and Access (CSM) • Historical Records (SI & ASR) • Presence of MEC items on the surface or subsurface in prescribed transects and grids (Trails and beaches only in MRS 13). MRS 13 further evaluated with surface reconnaissance results from 2009 post award site visit. • Concentration value of MC taken from discrete surface soil, subsurface soil, surface water, sediment, and groundwater samples, including step-out areas if applicable. One (1) discrete sample per applicable media, per location. • Hydraulic conductivity established from slug test data.
4. Define the Study Boundary	The MRS boundary defines the population to be sampled and the decision unit to which the data will be applied. The populations of MEC to be sampled are on the surface and subsurface within the MRSs. The populations to be sampled for MC are surface and subsurface soil, surface water, and sediment. <u>MEC:</u> • Locations on the *surface* and *subsurface* within the MRSs (Analog mag-and-dig on trails and beaches in MRS 13). MRS 13 investigation supplemented by 2009 visual surface reconnaissance from post award site visit. <u>MC:</u> • Surface and subsurface soil sampling locations will be established based on locations of MEC/MD discovered during the geophysical investigation. Surface water samples will be collected in areas near streams and shorelines down gradient from areas containing MEC/MD discovered during the geophysical investigation • Surface water and sediment samples will be collected from down gradient streams and depositional areas down gradient from areas containing MEC/MD discovered during the geophysical investigation.

Step	Culebra Island MRSs (Terrestrial)
	• Groundwater samples will be collected from wells identified in the groundwater survey, and any well that is installed. Note: For the purposes of this DQO, areas to be evaluated must be accessible. An "accessible" area is defined as one where access has not been hindered by slopes in excess of 33 degrees, dense vegetation, natural barriers, or any combination of the above.
5. Develop a Decision Rule	The following decision rules will be applied to the MEC population and decision unit: • If MEC is discovered on the surface and/or subsurface of an MRS then a baseline MEC Hazard Assessment (HA) based on future land use, potential receptors, and access will be performed and presented to the project team for further evaluation. • The MEC investigation will be halted if and when project objectives are met, (e.g., nature and extent of MEC has been determined for an MRS or a portion of an MRS*.) If the project objectives for MEC have not been met, grid or transecting step out processes will be implemented to collect additional data required to further bound the nature and extent of MEC contamination. * Criteria taken from EM-1110-1-4009, Chapter 7, Site Characterization. The following decision rules will be applied to the MC population and decision unit: <u>Surface and Subsurface Soil</u>: If MC concentrations for each sample site are less than the screening values identified in Worksheet #15 of the UFP QAPP, then no further action for that area will be considered as it is delineated. If MC concentrations for each sample site are greater than the screening values identified in Worksheet #15, Step-out sampling will be conducted IAW the Step-out procedure Flow Chart included in the Sampling and Analysis Plan (SAP) in Appendix E of the WP. Step-out sampling will continue until MC concentration is at or below screening criteria, in which the contamination shall be delineated. <u>Surface water and sediment:</u> If MC concentrations for all sample sites are less than the screening values identified in Worksheet #15, then surface water at that site will not be considered to impact surface water or sediments within the MRSs. If a concentration exceeds the screening values for a given location, additional downstream samples will be collected until MC concentration is at or below screening criteria, in which the contamination shall be delineated. <u>Groundwater</u> If MC concentrations for all sample sites are less than the screening values identified in Worksheet #15 of QAPP, then MC at that MRS will not be considered to impact groundwater. If a concentration exceeds the screening values for a given location, a determination will be made by the PDT if more samples are needed to delineate contamination.
6. Specify Limits on Decision Errors.	Measurable decision errors are limited to the field and analytical QC processes. The analytical requirements for MC are defined on Worksheet #12 of the UFP QAPP. Slug testing procedures are defined in the Aquifer Testing SOP included in Appendix K of the WP.
7. Optimize the Design for Obtaining Data	Data collection procedures and associated QC for MEC are included in the RI/FS WP. MC sample design and rationale is listed on Worksheet #17 of the UFP QAPP.

3.5.2.1 DGM and Investigation of Geophysical Anomalies

DGM was conducted to determine the location and concentration of anomalies which could be MEC. DGM was conducted in upland areas of the Culebra Island MRSs along the planned DGM transects to establish where high density areas were located. The high density maps for each MRS in which DGM transects and 50 foot by 50 foot grids were completed can be found in Appendix A Maps: Figures A-9 to A-13. Per a USFWS request, the upland area grids in MRS 13 were replaced with analog transect investigation of trails as a less destructive method of investigation to the environment. Only anomalies meeting the established threshold and classification (i.e., attributed to MEC) were investigated. DGM activities were considered complete when the selected DGM anomalies were investigated and sufficient data was collected to support the FS. The DQOs for DGM activities were met for MRSs 08, 09, 10 and 11 utilizing the data gathered during the RI. Although ROE and steep terrain affected the originally designed DGM investigation for MRS 06 the data collected in the RI, supported by information from historical sources per the DQO inputs [Archive Search Report Findings for Culebra Island National Wildlife Refuge, Culebra, Puerto Rico.(USACE Feb 1995) and Supplemental Archive Search Report Findings for Culebra Island National Wildlife Refuge, Culebra, Puerto Rico (USACE Sep 2005)], the SI fieldwork and findings during the Culebra Island Site SI (Parsons 2007) all contributed to meeting project DQOs for MRS 06. The MRS 13 2009 post-award site visit, along with the Culebra Island Site SI (Parsons 2007), contribute to meeting project DQOs for MRS 13.

All QC considerations were met and are documented in Appendix K.

3.5.2.2 Analog Mag-and-Dig Investigations

Analog Mag-and-Dig investigations were conducted along the accessible beach areas of the Culebra Island MRSs and on selected accessible trails on MRS 13 Appendix A: Figure A-3 through A-8. Anomaly selections for each beach were pre-established in the field investigation section of the WP and were based on the PWS. Teams flagged all analog anomalies for evaluation. Anomalies were selected for intrusive investigation by the field team management personnel after evaluating the magnetic analog signatures of the anomalies and prioritizing the most probable contacts that might produce MEC or MD. This allowed for anomalies to be investigated prior to beach changes and sand migration due to sea and surf conditions. The selected anomalies were intrusively investigated and sufficient data was collected to support the FS. The DQOs for analog mag-and-dig activities conducted at the Culebra MRSs were met. Table 3-3 provides the Analog Mag and Dig Investigation requirements from the USACE approved WP for the MRS beaches based from the PWS.

Table 3-3: Beach Area Analog Intrusive Investigations

MRS	Designed Intrusive Investigations (acres)	Completed Intrusive Investigations (acres)	Percentage Completed
06	45	58	128%
08	25	27	108%
09	20	26	130%
10	35	41	117%
11	40	64	160%
13	350	408	134%

3.5.2.3 MC Sampling

Environmental sampling was conducted during the field activities to assess for the presence of MC contamination at sites where MEC or MD was encountered during the RI, and at sites where demolition activities occurred. In accordance with the USACE-approved FSP and QAPP, environmental samples were collected from their respective media (Section 4.2). Sampling activities during the RI culminated in the collection of 90 environmental samples in the 2011/2012 sampling effort. The re-sampling effort in 2016/2017 resulted in collection of 100 samples analyzed for explosives, and 16 samples analyzed for metals. (The eight planned samples for metals analyzsis collected in 2016 were collected again to ensure preparation was the same as the preparation for metals analyzed in 2011/2012.) The additional groundwater sampling resulted in four samples plus one QA and one duplicate.

Stage 2B and Stage 4 data validation was performed. Data validation for the 2011/2012 sampling was performed in accordance with the DoD Quality Systems Manual (QSM) for Environmental Laboratories, Version 4.2 (October 2010), the USEPA National Functional Guidelines (NFG) for Superfund Organic Methods Data Review (June 2008) and for Inorganic Data Review, January 2010.

Data validation for the 2013 groundwater sample results was performed in accordance with the USACE 200-1-10, Guidance for Evaluation Performance Based Data (June 2005), NFG for Inorganic Data Review (EPA, 2004), and NFG for Organic Data Review (EPA, 2008) for application of professional judgement. If there is any gap, project specific UFP QAPP was used. Flagging was done according to DoD QSM Version 4.2 (October 2010).

Data validation for the 2016/2017 re-sampling effort was performed in accordance with the DoD QSM for Environmental Laboratories, Version 5.0 (July 2013) and a modified outline of the USEPA NFG for Superfund Organic Methods Data Review (August 2014). Where specific guidance was not available, the data has been evaluated in a conservative manner consistent with industry standards using professional experience. The DQOs for the collection, processing, and reporting of environmental samples are presented in the USACE-approved SAP in Appendix E of the WP. Sampling was conducted in accordance with the 2011 MC QAPP refined with results from the MEC investigation and updated in November 2013 to include a groundwater investigation.

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CHAPTER 4. CHARACTERIZATION OF MEC AND MC

This RI was performed in a manner consistent with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Section 104, and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), Sections 300.120(d)-300.400(e). Therefore, no federal, state, or local permits are required for any action taken on the site. The RI adheres to the DERP for FUDS and relevant U.S. Army Regulations and guidance for MEC programs.

4.1 MEC Characterization

4.1.1 General

This section provides details of the approach, methods, and operational procedures used for the geophysical data acquisition and associated data processing and intrusive investigation activities conducted for the characterization of MEC within the Culebra Island MRSs.

4.1.2 Identification of MEC Areas of Concern

The MEC areas of concern for the RI consisted of MRSs 06, 08, 09, 10, 11, and 13. The MEC areas of concern and history of the sites are described in detail in Chapter 2.

4.1.3 Site Access: Rights-of-Entry and Terrain Challenges

Prior to conducting RI field work, USA assisted the USACE in obtaining Rights-of-Entry (ROE) for all privately owned properties within the Culebra Island MRSs under the RI. ROE forms were mailed out in English and translated into Spanish as needed, a speaking local resident was hired to discuss with residents. ROE documents were executed by the USACE Jacksonville District Real Estate Office. All ROE documents related to the RI were tracked in a geographical information system (GIS) as they progressed through execution (Owner and USACE signatures) (see Appendix A: Figure A-37). Property data was obtained in GIS format from the (Puerto Rico) CRIM. The CRIM is the official property tax collection agency of Puerto Rico. RI field work was conducted only in those properties where a ROE document had been executed. Sufficient ROE was obtained in all Culebra Island MRSs with the exception of MRS 06, where the RI transect design had to be adjusted to fit within areas where ROE was granted. The areas where ROE was not obtained are shown in Appendix A (see Appendix A: Figure A-31, and Figures A-33 through A-35). For MRS 08 and MRS 13, ROEs were received for the full proposed RI field efforts.

Characterization was additionally impacted by unsafe slopes. Steep slopes were encountered throughout the MRSs. A generalized depiction of the slopes over 33 degrees is represented on Appendix A: Figures A-31 through A-36. A clinometer was used by the field teams to determine the angle in which slopes exceeded 33 degrees and therefore were considered unsafe to traverse for survey or investigation teams. In a few instances when the slope exceeded 33 degrees and the terrain still allowed for a transect to be surveyed or investigated, the UXOSO authorized the investigation to proceed.

As previously mentioned, MRSs 08, 09, 10, 11, and 13 were completed with minimal impacts from the lack of ROE or steep slopes. MRS 06 required a revision in the transects and grid

design due to the lack of ROE and steep slopes. Figures A-31 through A-36 provide the completed transects and grids overlaid onto the historical features that depict DoD munitions use. Only MRS 06 was shown to have historical features that were suspected of DoD munitions use that were not investigated due to the lack of ROE or steep slopes. The features for MRS 06 that were not investigated were designated as artillery firing points with the exception of one ammo storage site [the ammo storage site was investigated during the SI (Parsons 2007)].

4.1.4 RI MEC Characterization Tasks

4.1.4.1 Vegetation Removal

Vegetation removal activities were conducted in undeveloped areas to provide access for DGM surveys on transects and grids. Vegetation teams consisted of UXO qualified personnel and subcontracted deforester labor. Prior to commencing with vegetation removal activities, a local field biologist provided the vegetation removal teams with training in endangered species identification and mitigation procedures. This training was in coordination with the endangered species mitigation SOPs (Appendix M of the WP). The Team Leader utilized a Trimble Pro XRT Differential Global Positioning System (DGPS), or equivalent, to follow each transect, following a path of least resistance to help minimize devegetation and avoiding all properties where a ROE had not been obtained. Vegetation removal teams utilized handheld saws and cutters to clear the footprints needed, a path approximately 5 feet wide for transects and a 50-foot x 50-foot area for grids.

While conducting vegetation removal activities in MRS 09, UXO Technicians recovered two Mk 25 Marine Markers in close proximity to each other. These items were expended and likely not MEC, but because the shape of the items inhibited full evaluation, they were identified as MEC. The items were deemed acceptable to move, and were disposed of by a demolition shot on 26 May 2011 located within MRS 09. The Mk 25 Marine Marker is used by both civilian and military marine activity and it is uncertain whether the items are related to DoD site use. They likely washed up on shore after functioning over water. The location where the items were found and the location where the demolition was conducted are shown on Appendix A: Figure A-28 and A-33. It should be noted this type of munition is incidental to the site and not necessarily indicative of DoD impact to the MRS. The Mk 25 Marine Markers are also frequently used by civilian vessels for training/man overboard indicators. These items were either washed up onto the shore or were picked up and placed on the shore. The Mk 25 Marine Markers are not used on land. They are incidental finds that cannot be used to characterize the land portion of the MRS regarding DoD use.

Photograph 4-1: Vegetation Removal

4.1.4.2 Geophysical Investigation

This section provides details of the approach, methods, and operational procedures for the geophysical surveying and associated data processing for the RI. The geophysical investigation for the upland areas of all MRSs except MRS 13 included DGM data collection along transects and in established grids. Per USFWS request, MRS 13 instrument-assisted reconnaissance was performed in lieu of DGM along all known upland trails and roads to identify surface MEC. Analog Mag-and-Dig was the investigation method chosen for the accessible beach areas due to the potential for anomaly migration along the shore lines.

4.1.4.2.1 Geophysical System Verification

Based on a previous agreement obtained during the TPP, a Geophysical Prove-Out (GPO) would not be required and was replaced with a Geophysical System Verification (GSV) with an Instrument Verification Strip (IVS) Plan and Report. The IVS was located on the PRDNER property in Mortar and Combat Range Area MRS 05. The complete GSV report is provided in Appendix K. Further details regarding the selection of the location, test items, and procedures followed are located in the report. In lieu of a GPO, daily analog and digital instrument response tests were performed each morning and afternoon over the IVS. A combination of small Industry Standard Objects (ISOs), intended to simulate 37mm projectiles, and large ISOs, intended to simulate 105mm projectiles or 4.2 inch mortars, were used in each IVS. The response curves for these ISOs are well documented for both the best case orientation (vertical) and the worst case orientation (horizontal). Four of each ISO were used: two horizontal at depths 3 and 7 times ISO diameter, and two vertical at the same 3 and 7 times diameter depth. EM61-MK2 responses for each seed item were compared to published response curves and daily repeatability to ensure the equipment performed as designed.

The test strip results and anomaly selection criteria were provided to the USACE Geophysicist prior to starting fieldwork. Any recommended changes to the anomaly selection criteria were discussed with USACE's Geophysicist prior to implementing. USA documented the GSV results in a Draft and Final Geophysical System Verification letter report (the Final GSV Report is provided in Appendix K) that documented IVS setup, digital geophysical detection results, grid line spacing test results, initial grid anomaly selection criteria, and recommended final DGM performance metrics. The test strip was installed in a designated area at the USFWS facility located on Culebra.

Photograph 4-2: Survey of IVS

4.1.4.2.2 Geophysical Investigation Plan

Subsequent to the acceptance of the GSV, USA proceeded to collect DGM transect data to satisfy the project DQOs of the RI. Transect acres were converted to miles, as provided for in the PWS. All required grid acres were assigned to upland portions of each MRS (except MRS 13 where only accessible trails were investigated). Table 4-1 provides the designed transect and grid geophysical terrestrial acreage for each of the Culebra Island MRSs. Table 4-3 provides the investigated geophysical terrestrial acres during the RI field work. Appendix A: Figures A-3 through A-8 show the design for geophysical investigation coverage for each MRS. USA completed 21% over the designed geophysical acres.

Table 4-1: Project Designed Geophysical Survey Coverage (Acreage)

MRS	Land Acres	Design DGM Transect Acres	Design Grid Acres	Design Analog Transect Acres	Design Geophysical Acres	WP Designed Percentage of Land Acres
6	826	3.02	1	1.05	5.07	0.61%
8	306	1.44	0.5	0.35	2.29	0.75%
9	203	1.08	0.98	0.15	2.21	1.09%
10	522	4.18	0.98	0.29	5.45	1.04%
11	694.3	4.55	0.98	1.06	6.59	0.95%
13	484	0	0	2	2	0.41%

Note: The land acres in this table show the original acreages in place at the time of project planning and have not been updated to reflect the 2017 INPR acreage changes.

Table 4-2: Completed Geophysical Survey Coverage (Acreage)

MRS	Land Acres	Completed DGM Transect Acres	Completed Grid Acres	Completed Analog Transect Acres	Completed Geophysical Acres	Percentage of Land Acres Investigated
6	826	3.44	0.97	1.05	5.46	0.66%
8	306	1.52	0.52	0.36	2.4	0.78%
9	197.4	1.75	0.98	0.15	2.88	1.46%
10	522	4.81	0.89	0.29	5.99	1.15%
11	694.3	5.12	0.97	1.06	7.15	1.03%
13	334.2	0	0	3.33	3.33	1.0%

Note: The land acres shown in this table reflect the acreages established in the 2017 INPR, and the resulting percentage of land acres investigated.

Transects were planned and conducted for each MRS, focusing on historical munitions use areas, covering as much of the MRS, including all beach areas, as executed ROE would allow. MRS terrain maps were used during the transect planning to follow MRS elevation contours as much as possible and to avoid slopes greater than 33 degrees.

4.1.4.2.3 DGM Surveys

Along upland transects, the EM61-MK2 was deployed in stretcher mode with the wide (1m) edge forward and positioned with a Trimble Pro XRT DGPS, with an external antenna mounted over the coil center. UXO technicians guided the DGM operators along each prepared transect using a Trimble GeoXT for guidance, following the path cleared and marked by the vegetation removal teams. Note: upland transects in MRS 13 were investigated by the analog mag-and-dig method. The DGM team maintained a field log book and up loaded survey data to the GIS daily. Selected DGM transect anomalies were loaded into the project GIS database and used to create anomaly density maps for each MRS. DGM performance metrics followed those listed in the PWS Table 7-1 Performance Requirements for RI/FS using DGM Methods. For purposes of data quality acceptance, the morning and afternoon transect data collections were considered two lots of DGM data.

DGM transect data was analyzed for potential MEC anomalies. These potential MEC anomalies were imported into the project GIS to create anomaly density maps, using ESRI's Spatial Analyst, for each MRS. The anomaly density maps for each MRS failed to identify any potential CMUAs or Target Impact areas with an expected anomaly density ≥50 anomalies per acre. Therefore the anomaly density scale was reduced to a maximum of 10 anomalies per acre to help identify any elevated anomaly density areas. The final anomaly density maps for each MRS were used to place investigation grids in elevated anomaly density areas throughout each MRS. Appendix A: Figures A-9 through A-13 show the resulting anomaly density maps for the Culebra Island MRSs. Proposed 50 feet x 50 feet grid locations were placed in the high density anomaly

areas to provide the necessary data to establish the nature and extent of MEC contamination. Grid location maps were submitted to the USACE Geophysicist for review and approval.

Grid locations were selected with one grid near the center or peak of the high density areas to provide information for removal action cost estimates. Other grids overlapping the edges of the high density area were used to better document the MEC extent at each high density area. DGM grid (corner) locations were staked out using the Pro XRT with the external antenna mounted to a telescoping range pole, capable of extending 25 feet. Each grid area was surveyed by the field biologist to avoid all critical habitat and endangered species. Once a grid was established and accepted by the field biologist, it was devegetated in the same manner as transects, with the edges of each grid extended approximately 5 feet to allow the DGM sensor/operators to safely turn around. The cleared grid was then seeded with a dynamic repeatability item (small ISO buried 3 to 7 times its diameter), and surveyed with the EM61-MK2, positioned with the traditional line, station, fiducials. Grid survey line spacing, necessary to reliably detect objects as small as a 37mm projectile were located every 2.5 feet. Grid coverage was 95% or greater at the 2.5 feet line spacing. All unavoidable obstacles in any grid were located with the Pro XRT and documented in the DGM maps. Grid anomalies were selected, as approved in the final GSV Report. DGM grid mapping resulted in 3,339 DGM anomalies. A total of 1,229 anomalies were selected for intrusive investigation between all six MRSs (Appendix K).

Dig lists and target maps for each DGM grid were provided to the USACE Geophysicist for review and approval. A recommended dig list of anomalies to intrusively investigate was created for each MRS. A decision was made by field teams to utilize the Whites DFX 300 all metals instrument in place of the EM61-MK2 as required by the USACE-approved WP. This decision was based on the re-growth of native vegetation along the previously cut transects to the degree it was compromising the team's ability to safely transport the EM61-MK2 equipment (stretcher-mode) to the grids. The field team's route to the grids was along these transects. The DFX 300 instruments are much smaller and easier to navigate through the thick re-growth of the vegetation along the previously cut transects. The change in equipment for the grid intrusive investigation was not initially approved by USACE, resulting in a Corrective Action Report (CAR) (included in Appendix G). Upon arrival at the grid, the DGM grid corners were re-located (the corners had been previously marked by the Pro XRT and then staked during the initial DGM phase). The DGM targets selected for investigation were located using traditional line, station, and fiducials per the WP, manually measuring out the X, Y intersects and marking the DGM Target locations. Since the EM61-MK2's could not be transported to the site safely, the DFX 300 (White's All Metals Detectors) were used to locate and flag all metallic detections within a 1-m radius from the X, Y location pulled from the established grid corners. The teams then excavated a 1-m radius around the X, Y location after confirming the presence of metals with the DFX 300. Excavation proceeded down to bedrock to ensure that the DGM target was fully prosecuted laterally and vertically. All anomalies were identified, flagged, excavated, and removed. Clearing all metallic objects within a 1-m radius, down to bedrock, ensured that the selected DGM targets were all successfully resolved. The successful recovery of all BSIs, within the location accuracy tolerance (see DGM Culebra RI Access Database in Appendix J) and the successful post-intrusive QC checks all reinforce that the selected DGM anomalies were all resolved.

During the issuance of the CAR, an evaluation of the process and procedures used to require, locate, and excavate the DGM anomalies was conducted to determine if there were negative

impacts to the DQOs or the RI results due to the unauthorized equipment change. Though the use of the DFX 300's was not listed as an option within the USACE-approved WP, the use of the DFX 300 and other similar metal detectors is often used in place of or as an alternative to the EM 61 for reacquisition of DGM anomalies. The DFX 300 was the approved analog sensor for all analog transects performed on this project. For these reasons, along with the processes used for excavation and removal of all ferrous and nonferrous anomalies from the holes that were excavated, the USACE accepted the work completed.

Upon USA's response to the CAR and the implementation of corrective measures, it was determined that the change in the DGM anomaly detection equipment did not adversely affect the data quality of intrusive investigation of the grids and the investigation of the selected anomalies was completed to the satisfaction of the USACE.

Photograph 4-3: DGM Transect Survey

4.1.4.2.4 Anomaly Reacquisition and Intrusive Investigations (Grids)

Reacquisition and intrusive investigations were conducted on selected grid locations proposed by USA and approved by the USAESCH Geophysicist. Grid anomalies are selected using the same selection threshold and classification criteria established during the GSV and documented in the GSV report. The selections were reviewed by the Project Geophysicist and the USAESCH Geophysicist. The Intrusive Investigations were conducted in accordance with the USACE-approved WP by two UXO qualified teams led by UXO Technicians III serving as Team Leaders. The SUXOS, UXOQCS and UXOSO provided oversight for safety and quality. Intrusive investigations were conducted in upland grids (DGM anomalies) and accessible beach areas (analog anomalies). All excavations were completed by hand using shovels. All anomalies on dry land were excavated to a depth necessary for recovery. Two anomalies in MRS 13 were just inside the low tide line in an area off limits to the investigation IAW the USACE-approved WP and were not recovered. Anomaly depths were generally shallow overall, varying from 0 to 18 inches in the upland areas to 2 to 24 inches in the beach areas; one beach anomaly was encountered at 40 inches. Intrusive investigation teams utilized personal digital assistants (PDAs) to record the intrusive results. Intrusive results were uploaded to the intrusive database and project GIS for analysis. A summary of the intrusive results is presented in Table 4-3. Documentation of the intrusive investigation, including tabulated intrusive results, is included in

Appendix H. The field records for the intrusive investigations, including Site Manager's Daily Reports, Quality Control Daily Reports, and Safety Log, are presented in Appendix G.

As shown in Table 4-3, geological hot rock and non-MD accounted for the majority of the recovered items. During vegetation removal, two items (reported as MEC) were found on the surface at two locations in close proximity to each other in MRS 09: two Mk 25 Marine Markers. These Marine Markers were recovered on the surface along transects and not in the intrusive investigation grids, but are included in the results shown in the table. Although evaluation indicated the Marine Markers were expended and not likely MEC but MD, the interior of the items could not undergo a full evaluation and therefore the Marine Markers were destroyed by demolition. The items are used in both civilian and military marine activity and, as they are used for marine applications to mark a spot on the surface of the ocean by using smoke, the items are not related to DoD site use. MD, consisting of remnants of munitions, fuze parts, and expended small arms ammunition, was also recovered.

4.1.4.2.5 Analog Mag-and-Dig Transects

On the accessible beaches in each MRS and on accessible trails in MRS 13, intrusive teams used an analog sensor (White's DXF 300 All Metals Detector, which provided reliable results at the IVS) in the traditional Analog Mag-and-Dig mode, marking each anomaly with a plastic pin flag. During beach and beach buffer area transects, overlapping lines were used to cover each beach area 100%. All precautions necessary to avoid critical habitat or endangered species and to conduct safe boat operations were followed. Intrusive results were uploaded to the intrusive data base and project GIS for analysis. A summary of the intrusive results is presented in Table 4-3. Documentation of the intrusive investigation, including tabulated intrusive results, is included in Appendix H. The field records for the intrusive investigations, including Site Manager's Daily Reports, Quality Control Daily Reports, and Safety Log, are presented in Appendix G.

4.1.4.2.6 Surface Visual Reconnaissance Transects in MRS 13

The analog mag-and-dig investigation of the trails and beach areas in MRS 13 was augmented with a surface visual reconnaissance investigation conducted during a post award site visit. The investigation occurred as directed, primarily on trail areas cleared by the team (Appendix A: Figure A-36). This investigation was conducted without an ESP in place and the observations of the items were visual; the items were not handled and were left in place. These areas investigated by visual reconnaissance were not established/accessible trails and per the DQO for MRS 13 were not surveyed.

Photograph 4-4: Beach Analog Mag-and-Dig Investigations

Table 4-3: Summary of RI Intrusive Investigation Results

Investigation Type/MRS	Number of Locations						
	MEC	MD	Small Arms[1]	Other Debris	Hot Rock	Seed Items	Total
DGM Anomalies							
MRS 06	0	4	0	74	310	17	405
MRS 08	0	12	0	1	201	8	222
MRS 09	0	8	0	21	205	14	248
MRS 10	0	0	0	30	161	14	205
MRS 11	0	15	0	44	104	15	178
MRS 13	-	-	-	-	-	-	-
Analog Anomalies							
MRS 06	0	0	0	44	0	14	58
MRS 08	0	0	0	26	0	1	27
MRS09	2	0	0	20	0	4	26
MRS 10	0	0	0	35	0	6	41
MRS 11	0	2	0	38	0	24	64
MRS 13	0	10	2	304	72	20	408
Total	**2**	**51**	**2**	**637**	**1,053**	**137**	**1,882**

[1]-Small Arms Ammunition

Note: For MRS 13, the geophysical investigation was augmented with visual findings from surface reconnaissance conducted as part of a post award site visit in 2009. Those findings included MD from: 105mm projectiles (1-HE, 1-illumination, 4-unidentified), 5-inch projectiles (31), 3-inch projectiles (3), flares (8), fuzes, and other MD pieces.

4.1.4.2.7 Geophysical and Intrusive Investigation Quality Control

During the Culebra RI, all tasks performed received quality control checks and inspections, followed by quality assurance observations and inspections. Documentation consisting of logs, records, sheets, reports, and registers can be found in Appendix G. Field activities included, but were not limited to, vegetation removal for transects and grids, DGM of transects and grids, analog processing of transects, intrusive investigations of anomalies, soils sampling, and project documentation within the ACCESS database of all activities and their results. All final work has been accepted by the USACE.

Vegetation removal was accomplished on transects and grids to allow for ease of operations. The following data is found within the project database and excerpted here for summarization.

A comprehensive DGM Quality Control program was followed during production DGM. Daily instrument checks included:

- DGPS checks at IVS Seed Item #2 location
- Morning and Afternoon IVS checks
- Morning and Afternoon Static checks

Production DGM performance metrics were determined for the following:

- Production Transect and Grid Along Line Sample Separation
- Grid Internal Consistency (proper length and/or diagonal)
- Grid coverage
- Grid BSI detection

DGM QC results are delivered in the DGM ACCESS Database, included in Appendix K, along with the DGM data.

Analog geophysics Quality Control included the following:

- Daily Analog system (sensor and operator) daily checks
- Daily Geodetic DGPS Functionality check
- Analog Coverage Seeds
- Analog Blind Seed Items (BSIs)
- Analog Intrusive Acceptance Sampling

Analog QC results are delivered in the Analog ACCESS Database, included in Appendix K. Both the DGM and Analog Access databases were updated daily and delivered to the USACE QA Geophysicist weekly for their review and comment.

During the intrusive investigation activities the UXOQCS installed blind seed items (BSIs) in all DGM grids and beach analog areas, following standard anomaly avoidance procedures. BSIs were not installed along transects, as no intrusive operations were planned along them. Transect data was used to develop anomaly density maps which helped place DGM grids to determine the nature and extent of potential MEC contamination in each high density area. The small ISOs (37mm projectile simulant) were used as BSIs and were buried at depths between 3.9 in. (3 x

dia.) and 9.2 in. (7 x dia.) measured from ground surface to item center and a variety of orientations. The range of small ISO responses at the IVS was used to establish the expected range of BSI responses in production DGM grids.

The UXOQCS verified anomaly resolution of both the DGM and analog digs based on the allocation of investigations by MRS (Acceptance Sampling). The UXOQCS utilized the established criteria in the WP for the number of intrusive investigations allocated for DGM and analog, and the number of QC checks required for both to achieve a 70% confidence that there are <10% unresolved anomalies if MEC is detected and a 90% confidence that there are <5% unresolved anomalies if no MEC is detected as prescribed in the PWS, Tables 7-1 and 7-2. The number of QC checks in the WP was based on the calculations in Table 7-3 of the PWS, Acceptance Sampling Table for Anomaly Resolution. No QC failures were recorded during the RI. Quality Control Reports are included in Appendix G. The following table (Table 4-4) provides a summary of completed work that is found in the ACCESS data base in which data base entry required QC and USACE QA acceptance:

Table 4-4: Access Data Base Summary

Definable Features of Work	Completed Work
DGM Transects	44 transects totaling 34.54 miles (16.64 acres)
	• Number containing MD – 0
	• Number containing MEC – 0
	• Number containing MPPEH – 0
DGM Grids	77 Grids Investigated
	• Number containing MD – 17
	• Number containing MEC – 0
	• Number containing MPPEH – 0
DGM Targets	1,269 total investigated
	• Number of seed items recovered – 70
	• Number of MD items recovered – 38
	• Number of MEC items recovered –0
	• Number of MPPEH items recovered –0
	• Number of CD items recovered – 1161
	• Number of No Finds –1
Analog Transects	60 transects totaling 8.44 miles (6.24 acres)
	• Number containing MD – 6
	• Number containing MEC – 0
	• Number containing MPPEH – 2

Inspection of MD and disposition of MPPEH was accomplished following approved procedures and processes contained in the WP and SOPs. Final documentation of MPPEH is located in Appendix B.

4.1.5 Munitions Management

4.1.5.1 MEC Identification and Disposal

No MEC items related to DoD training at the site were recovered during intrusive investigations. However, two expended Mk 25 Marine Markers were discovered and reported as MEC, due to the interior of the items not being visible and could not undergo a full evaluation the Marine Markers were destroyed by demolition. The Marine Markers were discovered on the surface by UXO Technicians while conducting vegetation removal activities in MRS 09. These items were deemed acceptable to move by the SUXOS and UXOSO and were disposed of by a demolition shot on 26 May 2011. The demolition event was located within MRS 09. The two marine markers were recorded in the project MEC log accompanied by photographs (Appendix I); even though it is possible they are not related to DoD site use. The only other item recovered was a partial BDU-33 that was discovered during beach intrusive on MRS 13. This item was classified as MEC and deemed safe to move by the SUXOS and UXOSO and, with approval by the onsite USACE OESS, was transferred to MRS 09 to the same location as the two Mk 25 Marine Markers. A disposal event was conducted on 13 June 2011 where the BDU-33 was subsequently reclassified as Material Documented as Safe (MDAS). Two separate demolition/disposal events were conducted each at the same location in accordance with the Explosives Siting Plan (ESP), WP, and the demolition SOP. Prior to each demolition event, 24 to 36 hours' notice was provided in writing to the FAA, USCG, fire/police, and other local stakeholders. The demolition location is shown on Appendix A: Figure A-33. Copies of the demolition notices are included in Appendix E. A summary of the two demolition activities is shown on Table 4-5.

Table 4-5: Summary of Demolition Activities

Date	Location	Shot Time	Time Cleared	Munitions Destroyed
26 May 2011	MRS 09	15:30 local	16:00 local	(2) Mk 25 Marine Markers
13 June 2011	MRS 09	10:30 local	11:00 local	(1) partial BDU-33

All MD recovered from investigation and after demolition was inspected by the SUXOS, re-inspected by the UXOQCS, certified as MDAS, and documented on Form 1348 found in Appendix B. The MDAS was drummed, sealed and locked in secure storage until it was shipped offsite to TES for disposal, in a form where it could only be identified by its basic content. TES issued a Certificate of Destruction (COD), a copy of which has been provided in Appendix B. Pre and post detonation samples for MC analysis were collected in accordance with the MC QAPP Analytical results from the soil sampling can be found in Appendix C.

Photograph 4-5: Disposal of MEC Items in MRS 09

4.1.6 Underwater Visual Transects

USA conducted underwater visual survey along transects within 100 yards seaward of mean high tide in order to collect data that satisfy the project DQOs (USA, 2011). The investigation design limited the depth to not exceed recreational diving depths (120 feet). The visual and positioning data related to suspected MEC items was collected using a combination of a GPS-integrated underwater video system and VideoRay ROV system.

Items that reflect characteristics of MEC were investigated further with the ROV in order to capture video footage of the item and the surrounding underwater environment.

Where water depths and site conditions did not allow access by small boat, a visual surveys were completed using the VideoRay ROV deployed from shore, or a support boat situated in deeper surrounding waters.

Suspected MEC items or items of interest (items that have the visual characteristic or shape of MEC or MD but that cannot be confirmed visually as either) were encountered in MRS 11 and 13. These items and the areas surrounding them were further evaluated with an estimated 100-ft radius investigation of the item. The expanded survey was intended to identify any additional MEC like items located in close proximity, which may indicate the previous presence of a waterborne target or concentrated munitions use.

Table 4-6 provides a summary for the underwater visual transects. Appendix A: Figures A-14 to A-19 provide maps that describe the fieldwork results.

Table 4-6: Underwater Visual Transects

Location	Transect Design Acres	Completed Transect Acres	Completed Stepout Acres	Suspect MEC or Items of Interest
MRS 06	4.11	4.36	0	0
MRS 08	2.32	3.31	0	0
MRS 09	3.10	3.35	0	0
MRS 10	3.38	3.82	0	0
MRS 11	3.93	4.84	0.29	1
MRS 13	9.06	12.86	2.25	39

4.2 MC Characterization

4.2.1 General

This section provides details of the approach, methods, and operational procedures used for the sampling and analysis activities conducted for the characterization of MC at the Culebra Island MRSs. An MC SAP, comprised of a Field Sampling Plan (FSP) and a QAPP describing the sampling to be conducted during the RI was included with the USACE-approved WP and updated in October 2011 and November 2013.

4.2.2 MC Sampling Field Activities

Past military training activities at the Culebra Island MRSs may have resulted in the presence of MC contamination in areas where training may have occurred. These activities included sea-to-shore ranges, air-to-ground ranges, ground-based munitions, and aerial bombing targets. To determine whether chemical constituents associated with past training activities pose a risk to human health and the environment, a sampling and analysis program was conducted for existence of MC associated with historic munitions use at the site. An MC SAP was prepared to meet these objectives; the SAP was presented in Appendix E of the WP and described the sampling efforts to be conducted during the RI.

4.2.3 Purpose of MC Sampling Activities

An objective of the RI, as established during the TPP process, was to assess risk to human and ecological receptors due to the potential presence of MC in the soil, sediment, and surface water within the former Culebra Island MRSs and characterize impacts to these media at MEC and MD locations within the MRSs. The SAP was implemented to plan the collection of environmental data and assure that the quality of the data meets the needs of the end user. The sampling program achieves the sampling and analysis component of the Performance Work Statement (PWS) dated June 16, 2009. These objectives are:

- To characterize the nature and extent of MC, if present, and
- To provide sufficient information to assess risk, if any, to human health and the environment.

To achieve these objectives, environmental samples (i.e., soil, sediment, surface water) were collected based on recommendations presented in the SI Report (Parsons, 2007), from decisions made during the TPP meeting, and from locations where MEC might be encountered during the intrusive operations within the MRS. Groundwater samples were collected based on results of a Well Survey conducted in 2013 (USA 2013, Groundwater Survey Report). The Groundwater Survey Report can be found in Appendix O. All samples were collected in accordance with the project SAP. Sample locations and concentrations exceeding human health screening levels and ecological screening levels are described in further detail in the following paragraphs.

4.2.4 Sampling Rationale

Based on the CSM and DQOs for the Culebra Island MRSs, MC would be released to the environment only as a result of munitions-related activities that would have occurred in the various MRSs. If there was no evidence of munitions-related activities in a given area (e.g., MEC, MD/frag, target berms, ground scars), then there was no reason to expect that MC would have been released in that area. Therefore, the MC sampling effort focused on determining the presence of MC contamination associated with evidence of munitions-related activities. In areas with no evidence of munitions-related activities, sampling was not to be conducted. The sampling rationale for each MRS is summarized in the sections below.

No evidence of concentrated munitions use was found. Grids were placed over the locations where transects indicated metallic detections. Investigative sampling was conducted by collecting discrete samples in grids containing MD. When an exceedance was detected, step out sampling was conducted.

Samples were analyzed based on a MC list developed from historical records of munitions used at the site and included explosives and MC metals (aluminum, antimony, barium, chromium, copper, lead, mercury, and zinc). Groundwater analysis also included ammonium picrate and perchlorate. Sample methods by media type are included in Tables 4-8 to 4-18. Information regarding sample depths are presented below, by MRS. All samples were collected in accordance with the 2011 MC QAPP refined with results from the MEC investigation, and updated in November 2013 to include a groundwater investigation.

In September 2013 a well survey was conducted to evaluate existing wells for groundwater sampling, and the potential need for well installation. The results of the well survey are reported in the Groundwater Letter Report found in Appendix O. No evidence was found of the aquifer being used as a potable water supply. The groundwater survey discovered some existing wells were currently in use for irrigation or household purposes (washing clothes, cleaning). The PREQB estimates approximately 1,000 gallons per day of self-supplied water is in use.

The conclusion of the Letter Report was there are no existing wells that would deliver relevant results to evaluate DoD impacts to the island. Of all the wells surveyed, only two wells were identified as suitable for sampling, both were located in MRS 06. One was in the general vicinity of low densities of MD findings, the other was in the vicinity of an area identified as a land impact area. Two wells were installed, one in MRS 09 and one in MRS 11. Both MRSs had very low densities of MD findings. No MEC or MD were found in MRS 10. Therefore, since no MC source was present in the surface soil, no groundwater evaluation was conducted. The rationale for groundwater sampling was to evaluate impacts from military munitions. Characterizing the potability of groundwater throughout the Island of Culebra was not a DQO for this project.

4.2.4.1 MRS 06

MD was found in three of the DGM grids located in this MRS. Four MD items were found between three grids (06-03, 06-07 and 06-17). All MD was found on the surface. The other remaining grids contained no MD items. Based on the CSM, and the proposed MC release mechanism, areas with higher MEC/MD anomaly densities were expected to have the greatest potential to release MC to the environment. Grids 06-03, 06-07 and 06-17 were expected to have a lower potential of MC contamination than the grids in the other MRSs with 4 or more MD items, due to the lower MD densities observed during the geophysical and intrusive investigations. Therefore, one sample was collected within each of these grids. All samples were collected from 0 to 6 inches below ground surface (bgs) or until bedrock was encountered.

Explosives were detected at three locations of the five background samples (Samples: PR-0916-S0026 through -0030 and duplicate of PR-0916-S0030) collected from soil type Ts located in the Tidal Swamp soils within MRS 06. Therefore, the samples collected in 2011 for soil type Ts are not suitable for use as background samples and results from relocated samples will be used. No evidence of physical or historical DoD activity could be confirmed at the location where the samples were collected. The samples were collected less than 200 ft from a residence. Investigation in a nearby grid found an abundance of non-munitions related debris associated with construction and residential use, but no evidence of DoD training. Impacts from non-DoD use are probable at the location where explosives were detected.

Based on historical documentation of site use, all suspected DoD target areas in MRS 06 were investigated by either geophysical transects or grids. The RI findings of only four MD items discovered in the MRS, indicates there is no physical evidence that MRS 06 possessed a CMUA. Historical documents indicate that a tract of land was leased as an artillery range, on the southern shore of MRS 06 however there were no discoveries of MEC or MD at the suspected artillery range. Only one fragment (MD) item was discovered in the transects/grids within the southern acres of MRS 06 further supporting that either the artillery range was not used or lightly used or the fragment originated from outside of the MRS. Historical documents also indicate MRS 06 had multiple firing points but the documentation does not provide accurate locations. It is believed that these firing points were not established as fixed firing points where firing took place in high volume but rather approximate locations in which the artillery units could move and relocate their guns as needed. These firing points were used during a single exercise period (four firing points in 1937 and six firing points 1902 to 1903). Considering the light use of the firing points and the MC instability in the tropical environment which promotes degradation, the potential for the presence of MC is minimal. Considering the lack of discoveries of MEC and MD it is unlikely deposition of MC is present in the soil, surface water, sediment, and groundwater. Therefore, no surface water or sediment sampling was conducted. Groundwater from existing wells was sampled as a courtesy to regulators. There is no evidence MC is present in high enough concentrations in surface soil to migrate to groundwater.

Of 11 wells identified in MRS 06, only one existing well (6-9) was suitable for groundwater sampling. Well 6-6 was sampled, although it is a large-diameter well and likely does not accurately represent true groundwater conditions. Wells were considered suitable if a ROE was obtained, the well was used for appropriate reasons (i.e., not for sewage), the well is under control of the owner, and the well is closed to the elements (not a large diameter well exposed to contamination by other factors) (see Appendix A: Figure A-21). One well, 6-9, was in the

general vicinity of MD findings and the 1924 Firing Point. Well 6-6 was not in the vicinity of any MD identified in the RI, but was in an area identified from historical data as a Land Impact Area. Well 6-6 was in use for irrigation purposes, closed and under the control of the landowner. However, it was a large diameter well and may not be representative of true groundwater conditions.

4.2.4.2 MRS 08

MD was found in six of the DGM grids located in this MRS. Four MD items were found in both grids 08-02 and 08-03. The other four grids contained two or fewer MD items. MD was found in depths ranging from surface to 3 inches. Based on the CSM, and the proposed MC release mechanism, areas with higher MEC/MD anomaly densities were expected to have the greatest potential to release MC to the environment. Therefore, more samples were collected from grids 08-02 and 08-03, because these grids would most likely exhibit MC contamination, if present. Therefore, these grids were divided into quadrants of equal size, with one sample collected from a random location within each quadrant. The remaining grids (08-06, 08-07, 08-08, and 08-09) were expected to have a lower potential of MC contamination. Therefore, one sample was collected from a random location within each of these grids. All samples were collected from 0 to 6 inches bgs or until bedrock was encountered.

Historical documentation indicates that the western half of MRS 08 was part of Impact Area No. 2. Impact Area 2 was investigated with discoveries of 13 MD items all located within Impact Area 2. No MEC was discovered during the RI and there isn't any historical evidence indicating of past MEC discoveries on MRS 08.

This MRS was excluded from the groundwater evaluation due to an incomplete pathway.

4.2.4.3 MRS 09

MD was found in three of the DGM grids located in this MRS. Four MD items were found in grid 9-13. The other two grids contained two or fewer MD items. MD was found in depths ranging from the surface to 4 inches. Based on the CSM, and the proposed MC release mechanism, areas with higher MEC/MD anomaly densities were expected to have the greatest potential to release MC to the environment. Therefore, more samples were collected from grid 9-13, because this grid would most likely exhibit MC contamination, if present. Therefore, this grid was divided into equal sized quadrants, with one sample collected from a random location within each quadrant. The remaining grids (9-04 and 9-07) were expected to have a lower potential of MC contamination. Therefore, one sample was collected from a random location within each of these grids. All samples were collected from 0 to 6 inches bgs or until bedrock was encountered. In addition, three surface water and two sediment samples were collected in the lagoon downstream from grid 09-07.

Historical documentation indicated that an infantry direct fire area was used by DoD on the northern coastline of MRS 09. Transects and grids did not identify any MD within the identified direct fire area, however 4 MD items were discovered in Grid 9-13 which was located approximately 40 meters to the southeast of the direct fire area. Four MD items do not signify a heavily used target or CMUA but they do support MRS 09 northern acres in the approximate area of Grid 9-13 as being used for infantry training. A bombing target located inside Sueño Cove was investigated by both underwater ROV visual investigations and by transects placed

along the shoreline of the cove with no discoveries of MEC/MD or indications of DoD use. The western beach of MRS 09 was identified in historical documents as a Mortar Boat Firing Area. Beach transects along the shoreline and underwater ROV visual investigations were conducted with no discoveries of MEC/MD, however in grid 09-04 which is located midway between Sueño Cove and the beach on the western side of MRS 09 a single MD (fragment) was discovered. This MD item is not an indication of a target area or CMUA within MRS 09.

Of the 2 existing wells identified in MRS 09, neither was identified as suitable for sampling. One well was a large diameter well open to the elements and susceptible to contamination from non-DoD factors. The other well was submerged in a lagoon. Therefore, one well was installed in this MRS in the general vicinity of RI MD findings. The well location was changed from the original location selected due to development in the area. The location was in the vicinity of multiple targets, the Water Target in Sueño Cove, and an area that could receive over fire from the Mortar Boat Firing Area. The well was placed in an area downhill from the low densities of MD findings (see Appendix A: Figure A-23). The well depth was 30 feet and depth to groundwater at time of sampling was 21.4 feet. The well was screened from 10 to 30 feet bgs.

4.2.4.4 MRS 10

Although this was an area identified as a Direct Fire Area, there was no evidence of munitions-related activities in the 16 DGM grids places throughout the MRS or along the beach analog mag-and-dig transects evaluated at this MRS. There is no historical evidence of MEC or MD found in this area. Historical documents indicate that MRS 10 was used as a direct fire area, and beach defensive area. In addition Gun Mount #3 and Ammunition Storage Location were located in MRS 10. All of these sites were investigated by both grids and/or transects with no discoveries of MD/MEC or indications of DoD use. Field activities did not reveal evidence of metallic (target) debris or range features, there is no reason to suspect that the site was a concentrated munitions use area and sampling would not be justified based on the DQOs. Therefore, IAW the WP no MC sampling was conducted.

4.2.4.5 MRS 11

Similar to MRS 13, there were two beach areas that exhibited evidence of munitions-related activities in the form of MD/frag found along the beach during the intrusive investigation. MD was found in depths ranging from surface to 3 inches. These beaches are accessible to recreational users who may travel to the island. Therefore, MC sampling of these beaches was conducted to determine if there is evidence of a release of MC to soil at these beaches. Since it is expected that recreational users can be exposed to soil (sand) randomly at each of the beaches, a stratified random sampling approach was implemented for each of the beaches. Sample locations are shown on Appendix A: Figure A-24 and A-29. The beach sampling was focused in areas of MD findings along the transects. The area of the transect where MD was found was divided into eight equally sized segments. One sample was collected from a random location within each segment. Because of the dynamic nature of the beach sand, the samples were collected from a depth of 0 to 12 inches bgs.

In addition to the beach areas, MD was found in six of the DGM grids located at the northern portion of the MRS. Six MD items were found in grid 11-13 and three MD items were found in grid 11-15. The rest of the grids contained two or fewer MD items. MD was found in depths ranging from surface to 4 inches. Based on the CSM, and the proposed MC release mechanism,

areas with higher MEC/MD anomaly densities would be expected to have the greatest potential to release MC to the environment. Therefore, more samples were collected from grids 11-13 and 11-15, because these grids would most likely exhibit MC contamination, if present. Therefore, each of these grids was divided into equal sized quadrants, with one sample collected from a random location within each quadrant. The remaining grids (11-12, 11-14, 11-16, and 11-17) were expected to have a lower potential of MC contamination. Therefore, one sample was collected from a random location within each of these grids. All samples were collected from a maximum depth of 0 to 6 inches bgs or until bedrock was encountered. All samples were analyzed for explosives and MC metals in accordance with the FSP and QAPP.

Historical documents indicated that MRS 11 was used for DoD training in the southern acres as an infantry direct fire area. In Tamarindo Bay the shoreline is suspected to have been used as a firing point and a Mortar Boat Firing Area. These historical features were investigated by transects and or grids with no discoveries of MEC in the infantry direct fire area and one MD (fragment) discovered along the shoreline of Tamarindo Bay. The MD item discovered along the shoreline of Tamarindo Bay is not supportive of a firing point.

Of 15 wells evaluated in MRS 11, no wells were suitable for sampling. One well was broken off, one well not present, four were downhill from the landfill (one of these dry), three were covered by the landfill, ROE not obtained for three, and three had diameters ranging from 7.5 ft to 12 ft. Therefore, one well was installed in this MRS away from the landfill leachate and influences from development. The well was placed in an area downhill from MD findings. The well depth was 40 feet and depth to groundwater at time of sampling was 18.25 feet. The well was screened from 20 to 40 feet bgs.

4.2.4.6 MRS 13

The RI investigation identified evidence of munitions-related activities (MD only, no MEC) at four beaches on Cayo Louis Peña. Most MD items were found in depths ranging from surface to 12 inches, two items were found in coarse pebbly sand composed primarily of broken shells from depths of 18 and 30 inches. These beaches are accessible to recreational users who may travel to the island. Therefore, MC sampling of these beaches was conducted to determine if there is evidence of a release of MC to soil at these beaches. Since it is expected that recreational users can be exposed to soil (sand) randomly at each of the beaches, a stratified random sampling approach was proposed for each of the beaches. The beach sampling was focused in areas of MEC findings along the transects. The area of the transect where MEC was found was divided into eight equally sized segments. Each beach area (as identified by the length of the transects that were conducted during the MEC investigation) were divided into eight equally sized segments. One sample was collected from a random location within each segment. Because of the dynamic nature of the beach sand, the samples were collected from a depth of 0 to 12 inches bgs.

Historical documents indicate that the northeast peninsula of MRS 13 was a target area. This target area was not fully investigated during the RI as transects were not approved for vegetation removal by the land owner (USFWS). However previous investigations indicated a significant presence of MD. Some of the MD can be contributed as overshoot from the Northwest Peninsula and not the result of MRS 13 being used by DoD as a target area. The underwater ROV investigations and the discovery of MD in the form of empty 5-inch illumination projectiles further support that MRS 13 was an overshoot area for the NWP.

This MRS was excluded from the groundwater evaluation due to an incomplete pathway. The groundwater is not used as a potable water supply.

4.2.5 Sampling Locations

The DQO for MC characterization was developed through the TPP process. Parameters for sampling locations were as follows.

- Surface and subsurface soil sampling locations established based on locations of MEC/MD discovered during the geophysical investigation. The discrete sampling locations were biased to grids where MD was found, and randomly placed within the grids.
- Surface water and sediment samples to be collected from down gradient streams and depositional areas down gradient from areas containing MEC/MD discovered during the geophysical investigation.
- Groundwater samples collected from wells identified in the Well Survey and any installed wells at locations of suspected DoD impacts.

The following paragraphs summarize the sampling locations for each Culebra Island MRS.

4.2.5.1 Background Sample Locations

Forty-five background surface soil samples were collected from nine soil types (five samples per soil type) across Culebra Island that were not affected by historic DoD activities. The samples were collected from surface soil (0-2 inches bgs). Historical documentation was reviewed and samples were collected at locations where munitions use was unlikely (i.e. cantonment areas). All areas were screened to make sure no MEC or MD was found in the vicinity. Background sampling locations were paired to the respective soil map units as from the U.S. Department of Agriculture (USDA) soils map for Culebra (Puerto Rico, Humacao Area, Puerto Rico Eastern Part -PR689, Version 3, August 19, 2008). Five samples were collected at each location, four samples collected at ordinal locations 10 feet from a center sample.

Explosives were detected at three locations of the five background samples (Samples: PR-0916-S0026 through -0030, and duplicate of PR-0916-S0030) collected from soil type Tidal Swamp (Ts) located within MRS 06. Therefore, the samples collected in 2011 for soil type Ts are not suitable for use as background samples, the samples were re-located, and results from relocated samples are used in the RI Report. No evidence of historical DoD activity could be confirmed at the original 2011 Ts soil type location where the samples were collected; the location was 200 ft from a residence. Investigation in a nearby grid found an abundance of non-munitions related debris associated with construction and residential use, but no evidence of DoD training. The explosives detections are not attributed to DoD site use.

Three background surface water samples were collected from the banks of Cornello Lagoon, an area where historical documentation indicated was likely not affected by DoD activities. No background sediment samples were collected due to the coarse nature of the media present. No background groundwater samples were collected.

Background sample locations are presented in Appendix A: Figure A-20.

Because there was no MEC and no evidence of concentrated munitions use, no contamination was anticipated and a phased approach was followed for the groundwater investigation. The groundwater sampling results did not indicate a need for background samples.

4.2.5.2 MRS 06 Sampling Locations

A total of 17 surface soil samples were collected in MRS 06. Per the DQO for sampling locations, three locations corresponding to MD presence were sampled for soil (Grids 06-03, 06-07 and 06-17). A barium exceedance at Grid 06-17 resulted in the collection of 13 step-out samples (plus one field duplicate) to define the extent of the exceedances.

Explosives were detected at locations of three of the five background samples (Samples: PR-0916-S0026 through -0030, and duplicate of PR-0916-S0030) collected from soil type Ts, located within MRS 06. Therefore, the five background soil samples collected for soil type Ts were relocated and the updated results used in the RI Report. No evidence of physical or historical DoD activity could be confirmed at the location where the samples were collected. The samples were collected less than 200 ft from a residence. Investigation in a nearby grid found an abundance of non-munitions related debris associated with construction and residential use, but no evidence of DoD training. Impacts from non-DoD use are probable at the location where explosives were detected.

Two groundwater samples were collected from suitable existing wells in the MRS. Well 6-6 was located in the center of the MRS, well 6-9 in the vicinity of DoD activity. Appendix A: Figure A-25 and Figure A-26 present the sampling locations in MRS 06.

4.2.5.3 MRS 08 Sampling Locations

Per the DQO for sampling locations, six locations corresponding to MD presence were sampled for soil (Grids 08-02, 08-03, 08-06, 08-07, 08-08, and 08-09). Four surface soil samples were collected from Grids 08-02 and 08-03 since they contained the greatest amount of MD. One surface soil sample was collected in each of the other four grids. Appendix A: Figure A-27 presents the sampling locations in MRS 08. This MRS was excluded from the groundwater investigation.

4.2.5.4 MRS 09 Sampling Locations

Per the DQO for sampling locations, four locations corresponding to MD presence were sampled for soil (Grids 09-04, 09-07, and 09-13). Four soil samples were collected from Grid 09-13 since it contained the greatest amount of MD. One soil sample was collected in each of the other two grids. Three sets of sediment and surface water samples were collected from a lagoon located behind Sueño Cove. One groundwater sample was collected from a well installed in the vicinity of a grid with MD findings near Soldado Point. Appendix A: Figure A-28 presents the sampling locations in MRS 09.

4.2.5.5 MRS 10 Sampling Locations

Per the DQO for sampling locations, no samples were collected as no MEC or MD were recovered during the geophysical investigations.

4.2.5.6 MRS 11 Sampling Locations

MRS 11 North per the DQO for sampling locations, eight locations corresponding to MD presence were sampled for soil (Grids 11-12, 11-13, 11-14, 11-15, 11-16, and 11-17; and Beach Transects 11M-08 and 11M-11). Four soil samples were collected from Grids 11-13 and 11-15 since they contained the greatest amount of MD. One soil sample was collected in each of the other four grids. Eight soil samples were collected along both Beach Transects 11M-08 and 11M-1. One groundwater sample was collected from a well installed downhill from MD findings away from contamination from non-DoD sources.

Appendix A: Figure A-29 presents the sampling locations in MRS 11 North.

MRS 11 South produced no MEC or MD per the RI WP. If no evidence of munitions-related activities in a given area (e.g., MEC, MD/frag, target berms, ground scars) was identified, then there was no reason to expect that MC would have been released in that area. Therefore, the MC sampling effort that focused on determining the presence of MC contamination associated with evidence of munitions-related activities was not applicable; therefore, investigative MC sampling was not conducted in MRS 11 South.

Background surface water samples were collected from Cornello Lagoon in MRS 11. The media present in the lagoon was very coarse and not suitable for representative background sediment samples.

4.2.5.7 MRS 13 Sampling Locations

Per the DQO for sampling locations, four locations corresponding to MD presence were sampled for soil (Beach Transects 13M-21, 13M-22, 13M-18, and 13M-09). Eight soil samples were collected along each Beach Transect. This MRS was excluded from the groundwater investigation due to an incomplete pathway.

Appendix A: Figure A-30 presents the sampling locations in MRS 13.

4.2.6 Field Sampling Activities

Subsequent to completing Intrusive Investigations within each MRS, an environmental sampling team collected soil, surface water, and sediment samples per the DQOs and Field Sampling Plan (FSP) and QAPP found in Appendix E of the WP. Groundwater sampling was conducted in December 2013 as part of the groundwater evaluation later added to the investigation. Only wells located within the MRSs covered by this contract were evaluated in the groundwater investigation.

Due to the predominantly shallow soil profiles on Culebra (< 12 inches, on average), only surface soil samples were feasible. Although anomaly depths varied to 18 inches in the upland rocky areas, no MEC or MD was found below 3 inches in these areas, therefore, subsurface sampling was not conducted. Bedrock outcrops, areas where subsurface soil is either non-existent or minimally present, are predominantly found in soil type Rock Land (abbreviated as Rs and shown on Figure A-20, Culebra Background Sample Locations). The Rs soil type also has slopes ranging up to 60 to 70 percent which inhibit deposition. Other areas of steep slopes are located on Figures A-31 through A36.

In the beach areas, per the QAPP refined in October 2011 to reflect results from the MEC investigation, soil samples were collected from 0 to 12 inches, due to the dynamic nature of

beach environments. All MD was found within this depth interval except for two items collected at depths of 18 to 40 inches. The beach conditions in these areas were comprised of large (coarse) pieces of broken coral and shells and were not adequate media for sampling.

Surface water and sediment samples were collected only in terrestrial water bodies down gradient from investigation grids containing MEC or MD. MRS 09 was the only area that required surface water and sediment sampling per the DQO. Anomaly avoidance was performed at sample locations using a White's DXF 399 All Metals Detector.

All sampling locations are shown on Figures A-20 through A-30.

Initial plans called for use of the Innov-X metal detector. However, the Innov-X was not useable at the site and was replaced with additional step-out samples in areas that indicated PSV exceedances.

During the 28 February 2006 TPP Meeting for the SI (Parsons, 2007), the PREQB agreed that because there are no known cases where groundwater is used for consumption on Culebra Island, Parsons would forgo groundwater sampling during the 2007 SI phase, and groundwater would be further evaluated during a subsequent RI/FS if a complete pathway was identified during the 2007 SI. The 2007 SI found no identifiable receptors that could result in a complete exposure pathway for MC via groundwater use. During research for the 2007 SI, three documents on groundwater usage were identified. A 1995 study, *Water Wells on Isla de Culebra, Puerto Rico*, listed 77 wells on the island of Culebra, of which only 16 were being used for any purpose (Cherry, 1995). The report states that well water from 10 wells was being used to flush toilets, water and clean horses, water livestock, and water plants. The remaining six wells were listed as being owned by the PRASA; however, only two were listed as being pumped, and no information was provided about the use of this water (Parsons, 2007).

The second report, *Puerto Rico Water Use Program: Public-Supply Water Use and Wastewater Disposal During 1990*, shows the rate of withdrawal in millions of gallons per day as zero for Culebra (as cited in Veve and Taggart, 1996).

The third report, *Estimated Water Use in Puerto Rico, 2000* (Molina-Rivera, 2000) is a USGS Open File Report that was prepared in cooperation with PRASA and provides information to support the fact that no use or withdrawal from a public water supply was ongoing in Culebra as of 2000. The public was supplied with water pumped in from off-island aquifers. The water supply source has not changed since then. The report does not provide facts to confirm or deny domestic self-supplied water use, just an estimation of domestic self-supplied water use based on public supply water withdrawal use. For Culebra, the report estimates no current domestic self-supplied water use. However, the groundwater survey discovered some existing wells were used for irrigation or household purposes (washing clothes, cleaning). The PREQB estimates approximately 1,000 gallons per day of self-supplied water is used for household purposes.

The fourth report, *Hydrogeology of Puerto Rico and the Outlying Islands of Vieques, Culebra, and Mona* (USGS 2014). This report was prepared per the request of the Commonwealth of Puerto Rico, in particular the PRDNER, to assist the Commonwealth with the management of its groundwater resources. The report states:

> "Aquifers on Culebra Island are formed by volcanic rocks and alluvial deposits underlying the coastal embayments. The total estimated thickness of the unconsolidated deposits in the embayments (alluvium and weathered rock) is less

> than 18 m. Most wells on the island of Culebra are shallow, dug wells that supply water to livestock. To augment the water supply of the island, several wells were drilled within an upland depression; however, the sustained yield of these wells was less than 20 m^3/day. An underwater pipeline connecting Culebra to the public water supply of Vieques Island was constructed around 1989." The report then summarizes, "In the outlying islands of Vieques, Culebra, and Mona, only Vieques is underlain by aquifers of any local importance."

A groundwater survey was conducted in 2013 (to honor a request by PRDNER) to evaluate wells referenced in the 1995 Cherry report and any newly installed wells. The full results from this well survey are presented in a Letter Report located in Appendix O. Two wells were identified as suitable for sampling, both located in MRS 06. Well suitability was based on a variety of factors, the first of which included protection of the well from the elements (many wells were very large diameter wells ranging from two to 18 feet in diameter and open to the elements and non-DoD sources of contamination). Other factors considered for exclusion of wells include use of the well for sewage disposal, location of the well down gradient from the landfill, a well-covered by landfill expansion, location of the well in an a chicken coop, a well that was broken, unusable, or sealed off, a well submerged in a lagoon, or a well location for which ROE was not obtained. The wells were located using the coordinates from the Cherry Report (which per Mr. Cherry were very general and not accurate) and interviews with residents and the municipality. Two wells were installed and sampled, one in MRS 09 and one in MRS 11. One of the wells identified in MRS 06 was a large diameter well and may not reflect true groundwater conditions. However, it was under control of the owner and sampled for general information. No wells were identified as drinking water wells.

Sampling containers and shipping coolers were provided by the laboratories and contained the proper preservatives as specified in the SAP. The sampling team utilized a drop freezer set at the prescribed temperature for sample storage. Groundwater and Investigative Derived Waste (IDW) samples were kept on ice in coolers. One temperature blank was included in each cooler upon shipping. Sample shipments were manifested on a chain-of-custody (COC) form and were made weekly or as necessary to meet the extraction timeframes prescribed in the FSP and QAPP.

QA/QC, Field Duplicates, and Matrix Spike/ Matrix Spike Duplicate (MS/MSD) samples were collected in the frequencies specified in the FSP. These samples were shipped to the respective laboratories in the same manner as the primary samples.

4.2.6.1 Soil Sampling Procedures

Initial plans called for discrete surface soil samples (including discrete background soil samples) to be collected from 0 to 2 inches bgs (or to depth of bedrock if encountered first) using a sampling spoon. A subsequent sampling methodology was proposed during a teleconference held on 4 October 2011 where consensus was made on the sampling approach described below. The decisions were made following the initial geophysical investigation.

Based on the CSM and DQOs for these sites, MC would be released to the environment only as a result of munitions-related activities that would have occurred in the various MRSs. If there is no evidence of munitions-related activities in a given area (e.g., MEC, MD/frag, target berms, ground scars), there is no reason to expect that MC would have been released in that area. Therefore, the MC sampling effort was focused on determining the presence of MC

contamination associated with evidence of munitions-related activities. In areas with no evidence of munitions-related activities, no sampling was to be conducted.

Although the presence of MC contamination was unlikely, the highly dynamic beach areas were sampled to prove no contamination was present. The beach areas were sampled at a greater depth than the soil located away from the influences of wave action in an attempt to better capture any MC present. The sand grains offer little substrate for sorption and tidal pumping provides an ongoing flushing mechanism to clear contaminants which may have previously been present, or may be transported to a beach area. While finding MD and MEC in such an environment is very possible, it is unlikely that MC would be present this long after use of the area as a range stopped.

The sampling rationale for each MRS is summarized below. All samples were analyzed for explosives and MC metals.

MRS13: The MEC investigation identified evidence of munitions-related activities (MD and MPPEH) at four beaches on Cayo Louis Peña. These beaches are accessible to recreational users who may travel to the island. Therefore, MC sampling of these beaches was proposed to determine if there was evidence of a release of MC to soil at these beaches. Since it was expected that recreational users could be exposed to soil (sand) randomly at each of the beaches, a stratified random sampling approach was proposed for each of the beaches. Each beach area (as identified by the length of the transects that were conducted during the MEC investigation) was divided into eight equally sized segments. One sample was collected from a random location within each segment. Because of the dynamic nature of the beach sand, the samples were collected from a depth of 0 to 12 inches bgs.

MRS 11: Similar to MRS 13, there were two beach areas that exhibited evidence of munitions-related activities in the form of MD/frag found along the beach during the MEC investigation. These beaches are accessible to recreational users who may travel to the island. Therefore, MC sampling of these beaches was proposed to determine if there was evidence of a release of MC to soil at these beaches. Since it was expected that recreational users could be exposed to soil (sand) randomly at each of the beaches, a stratified random sampling approach was proposed for each of the beaches. Each beach area (as identified by the length of the transects that were conducted during the MEC investigation) was divided into eight equally sized segments. One sample was collected from a random location within each segment. Because of the dynamic nature of the beach sand, the samples were collected from a depth of 0 to 12 inches bgs.

In addition to the beach areas, MD was found in six of the DGM grids located at the northern portion of the MRS. Six MD items were found in grid 11-13 and three MD items were found in grid 11-15. The rest of the grids contained two or fewer MD items. Based on the CSM, and the proposed MC release mechanism, areas with higher MEC/MD anomaly densities were expected to have the greatest potential to release MC into the environment. Therefore, more samples were collected from grids 11-13 and 11-15, because these grids would most likely exhibit MC contamination, if present. Therefore, each of these grids were divided into equal sized quadrants, with one sample collected from a random location within each quadrant. The remaining grids (11-12, 11-14, 11-16, and 11-17) were expected to have a lower potential of MC contamination. Therefore, one sample was collected from a random location within each of these grids. All samples were collected from a maximum depth of 0 to 6 inches bgs (or to depth of bedrock if encountered first).

MRS 10: There was no evidence of munitions-related activities in the DGM grids evaluated at this MRS. Therefore, no MC sampling was planned.

MRS 09: MD was found in three of the DGM grids located in this MRS. Four MD items were found in grid 9-13. The other two grids contained two or fewer MD items. Based on the CSM, and the proposed MC release mechanism, areas with higher MEC/MD anomaly densities would have been expected to have the greatest potential to release MC to the environment. Therefore, more samples were collected from grid 9-13, because this grid would most likely exhibit MC contamination, if present. Therefore, this grid was divided into quadrants of equal sized, with one sample collected from a random location within each quadrant. The remaining grids (9-04 and 9-07) would have been expected to have a lower potential of MC contamination. Therefore, one sample was collected from a random location within each of these grids. All samples were collected from a maximum depth of 0 to 6 inches bgs (or to depth of bedrock if encountered first).

MRS 06 and MRS 08: At the time of the meeting establishing the sampling methodology (teleconference held on 4 October 2011), the MEC investigation had not yet been completed at these MRSs. However, it was anticipated that the sampling approach would follow the approach outlined for the grids in MRS 11 and MRS 09.

As mentioned above, the depth range was altered from the originally planned 0 to 2 inch bgs interval because most MD found in the RI was in the 0 to 6 inch bgs interval. Samples from beach sands were collected from the 0 to 12 inch interval to account for the dynamic nature of beach sand.

For each sample the sampler donned a new pair of disposable latex or nitrile gloves and used only clean, decontaminated sampling equipment for sample collection. All vegetation and plant debris was removed from the sampling point prior to sampling and borings with the soil removed from the hole were backfilled following sample collection. Each discrete sample was placed into a stainless steel or Pyrex bowl, mixed and then quartered. Each quarter was allocated to a sample jar until the jar was full. Samples were stored in a drop freezer set at the temperatures specified in the FSP and QAPP. Samples were packaged in coolers and shipped to the laboratories weekly. The Innov-X (XRF) metals detector was not used due to malfunction, and therefore, step out samples were collected at locations of PSV exceedances.

4.2.6.2 Surface Water and Sediment Sampling Procedures

In October 2011, surface water and sediment samples were planned to be collected in MRS 09 in lagoons downstream from grids 9-13, 9-04, and 9-07, if present. In addition, the lagoon in the middle of MRS 11, Laguna de Cornello, was planned to be sampled for background (water and sediment) for a total of 2 to 3 samples each. In MRS 09, one lagoon was present downstream from grid 09-07. Two surface water samples and three sediment samples were collected from this lagoon. No lagoons were available downstream of grids 9-04 or 9-07. The background water samples were collected from Laguna de Cornello, but the coarse-grained sediment present was not representative of the sediment in MRS 09 and the background sediment samples were not collected.

For each surface water and sediment sample the sampler donned a new pair of disposable latex or nitrile gloves and used only clean, decontaminated sampling equipment for sample collection. Surface water sample collection locations were deep enough so that the sample bottles were able

to be held upright during collection to avoid compromising the preservative. Downstream samples were collected first and disturbances during wading were avoided. When both water and sediment samples were collected, the water sample was collected first to avoid introducing additional sediment particles in the water sample.

After the sample bottle was filled, the cap was placed on the bottle and the bottle was packaged for shipment. Samples were stored in a drop freezer set at the temperatures specified in the FSP and QAPP. Samples were packaged in coolers and shipped to the laboratories weekly.

The sediment samples were collected furthest from the source locations first, to minimize the possibility of cross-contamination. Thereafter, the most downstream sediment samples were collected followed by the next upstream samples, if required. If surface water samples were taken at the same location, they were collected before the sediment samples. The addition of organic matter (leaves, grass, etc.) into the sediment samples was avoided. While facing upstream, the sample was collected by scooping along the bottom of the surface water body with a decontaminated plastic scoop. Excess water was removed from the scoop and sediment sample was placed into a decontaminated stainless steel bowl. After a sufficient sample volume was collected into the stainless steel bowl, the sample was homogenized, quartered and placed into the appropriate sample jars. After a sample bottle was filled, the cap was placed on the bottle and the bottle was packaged for shipment. Samples were stored in a drop freezer set at the temperatures specified in the FSP and QAPP. Samples were packaged in coolers and shipped to the laboratories weekly.

4.2.6.3 Groundwater Sampling Procedures

Four groundwater samples were collected at pre-approved locations; two from existing wells identified from the 2013 well survey Letter Report (plus one duplicate and one QA), and two from wells installed in support of the RI. The wells were purged using low-flow methods to stabilization of parameters. Purge water was collected, stored in 55-gallon drums and sampled for determination of disposal methods. The groundwater sampling followed procedures established in the 2013 WP revision to include groundwater sampling. The YSI Horiba water quality meter was used in the field for analysis of pH, conductivity, turbidity, dissolved oxygen, and temperature. Samples were analyzed by Agricultural Priority Pollutants Laboratory, Inc. (APPL) for MC metals, explosives, ammonium picrate, and perchlorate. Perchlorate samples were filtered with 0.2 micron filter, pre-filtering was not necessary. The samples were collected in pre-cleaned containers provided by the laboratory. Samples were kept on ice until shipment to the appropriate laboratory.

4.2.6.4 Composite Samples at Blow-in-Place Locations

Field teams collected pre- and post-detonation composite soil samples using the Cold Regions Research & Engineering Laboratory (CRREL) 7-sample wheel approach described in Engineer Research and Development Center (ERDC) Special Report 96-15, titled *Assessment of Sampling Error Associated with Collection and Analysis of Soil Samples at Explosives-Contaminated Sites.* For each sample, the sampler donned a new pair of disposable latex or nitrile gloves and used only clean, decontaminated sampling equipment for sample collection. Samples were stored in a drop freezer set at the temperatures specified in the SAP. Samples were packaged in coolers and shipped to the laboratories weekly.

4.2.7 Sampling Analysis

4.2.7.1 Soil, Surface Water and Sediment Samples

Soil, surface water, and sediment samples were shipped to RTI Laboratories (RTI), in Lithonia, Michigan. Samples submitted to RTI were analyzed by USEPA SW methods: explosives-8330A, and MC metals-3050A/6020A, mercury-7471A (soil and sediment); 3020A/6020A, mercury-7470A (surface water), in accordance with the FSP and QAPP. (Both 6010 and 6020 were approved in TPP meeting minutes). Due to cooler temperature exceedances upon arrival and exceedances of holding times, all investigative samples were re-collected in December 2016 for analysis of explosives by method 8330B at APPL, Inc., laboratory, in Clovis, California. Metals were not re-analyzed as they are not as sensitive to temperature and holding times were not exceeded. The background samples to represent MC metals for the Ts soil type were re-collected (due to explosive detections at the original locations) and analyzed by 3050A/6020A. One sediment sample was also analyzed for metals, to complete a data gap resulting from a broken container in the original 2011 sampling effort. MC metals identified from historical records of munitions used at the site included aluminum, antimony, barium, chromium, copper, lead, mercury, and zinc (see Appendix N). All analytical data were verified prior to being released by RTI and APPL. Verification included both editorial and technical reviews. Laboratory extraction, analysis methods, and target analytes were conducted in accordance with the WP.

Soil, surface water, and sediment QA samples of the 2011/2012 sampling events were shipped to TestAmerica, Inc. (TestAmerica), in Denver, Colorado, and to Accutest for the 2016/2017 re-sampling events. QA metals analysis by Test America was conducted by method SW 6010B (which differs from method 6020A performed at RTI), Accutest metals analysis was by 3050B/6020A and mercury by 7471B. No surface water samples were submitted to Test America. All analytical data were verified prior to being released by TestAmerica. Verification included both editorial and technical reviews. Laboratory extraction, analysis methods, and target analytes were conducted in accordance with the WP.

Once finalized by the laboratories, Laboratory Data Consultants, Inc. (LDC) validated all the analytical data generated by RTI and APPL during the soil, surface water, and sediment sampling effort in accordance with the requirements identified in the WP and QAPP. The validation included requirements in DoD Quality System Manual (QSM) version 3, USEPA SW 846 methods.

Some explosives samples required manual integration of peaks for target compound analysis per laboratory SOPs.

Data validation reports (DVR) were generated by LDC for all soil, surface water and sediment data packages and are provided in Appendix C. The data in the DVRs was summarized in two Quality Control Summary Reports (QCSRs) found in Appendix C, Folder 3 Data Validation and Usability, one for the RTI data, and one for the APPL data from the Re-Sampling. Parsons provided data validation for the groundwater data.

The QCSRs prepared by LDC provide a review of the overall quality of sample results for each sampling event. In the 2011/2012 sampling event, holding times for extraction of explosives were exceeded, sample temperatures exceeded 6°C (with some up to at 12°C) upon arrival at the RTI laboratory, and instrument calibration verification exceeded acceptance criteria for 9

explosives results. Based on these facts and the large number of non-detects, the explosives data for the investigative samples collected in 2011 and 2012 samples was deemed unusable. The investigative samples were recollected, analyzed for explosives, and the RI report updated.

No holding times were exceeded for metals. Although cooler temperatures upon receipt by the laboratory were logged in up to at 12°C, utilizing professional judgement, metals analyses were not validated as qualified since the compounds are not expected to degrade significantly during shipping or storage. The 2011/2012 metals results are evaluated as acceptable, and are used in the report.

The QCSR noted that based upon the Stage 2B and Stage 4 data validation, the tetryl results from samples collected at the demolition location that were rejected (R) in samples PR-0009-CPRE, PR-0010-CPRE, PR-0011-CPRE, PR-0012-CPRE, PR-0013-CPST, PR-0014-CPST, PR-0015-CPST, and PR-0016-CPST represent a major impact on data usability and were deemed unusable for all purposes. The post-demolition samples were re-collected, and the updated results are reported in this RI Report.

LDC prepared a second QCSR to summarize data validation of analysis at APPL laboratory for the re-sampling effort. All samples arrived at the laboratory properly preserved and none exceeded 6°C. No holding times for primary samples were exceeded.

Although no holding times were exceeded for primary samples, there was an issue with the Laboratory Control Sample for Sample Data Group 81628. The 8330B explosives analysis was initiallyextracted within the holding time. The technician realized the Standard Reference Material didn't contain all the target analytes, the technician re-analyzed the analytes with the correct reference material, but it was done 2 days past the hold time. APPL initially only reported the analysis past holding time, and has since revised the Lab Data Report to report both sets of results. The results reported within the holding time are used in this report, but the LCS for that sample only contained tetryl and 3,5-DNA. APPL initiated a Corrective Action Request (CAR) for not reporting both sets of data, and the CAR is provided in Appendix C,2-Lab Data, f-APPL Re-Sampling.

Other than the issues noted above, the overall assessment of the field sampling, QA/QC data review by automated and manual validation of the May 2011 through February 2012 data set met project requirements and completeness levels.

4.2.7.2 Groundwater Sample Analysis

Groundwater samples were shipped to APPL, Inc. in Clovis, California. Samples submitted to APPL were analyzed for eight MC metals (aluminum, antimony, barium, chromium, copper, lead, mercury, and zinc) by USEPA methods 6020A/7470A; explosives (8330B), ammonium picrate (8321A), and perchlorate (6850), chloride (USEPA 300.0), and nitrate/nitrite as N (USEPA 353.2) in accordance with the QAPP. QA and QC samples were collected according to the USACE approved WP. All analytical data were verified prior to being released by APPL. Verification included both editorial and technical reviews. Laboratory extraction, analysis methods, and target analytes were conducted in accordance with the WP.

Sample PR-CUL-GW-MRS-06-10 was collected as a duplicate of PR-CUL-GW-MRS-06-09. The QA sample (PR-CUL-GW-MRS-06-6 QA) was analyzed by Katahdin Analytical Services, Scarborough, Maine, with perchlorate analysis subcontracted to Microbac Laboratory. Due to

the limitation of finding a QA lab for the ammonium picrate analysis, APPL served as both primary lab and QA lab for the ammonium picrate analysis under the following conditions: (1) APPL used a different standard as the primary and second source as the parent sample; (2) APPL established a different initial calibration curve (ICAL) with different standard from the parent sample; (3) a different internally qualified technician extracted the QA sample than the primary sample; and (4) APPL will issue a separate lab data package for the QA sample with its own associated lab QC runs. This was approved via email by the Technical Manager of USACE on 22 Nov. 2013. Groundwater samples were validated by Parsons.

4.2.8 Establishment of Background and PSVs

4.2.8.1 Background Concentrations for Metals in Soil and Sediment

Background soil samples were collected from nine soil type areas, some were located outside the MRSs covered by the RI that a review of historical documentation indicated were not affected by DoD activities. The background soil samples were analyzed for metals using USEPA Methods: metals SW6020A, 7471A (mercury) and explosives 8330A. Complete analytical results for these analyses are included in Appendix C. For each soil type, since the number of samples was less than ten and the 95% Upper Tolerance Level (UTL) would not be appropriate, the background threshold values (BTVs) for metals were determined to be twice the mean concentration detected in the background soil samples; these BTVs are presented in Table 4-7.

Background samples for sediment were not collected because there was not an appropriate ambient sampling location for sediment. In the absence of usable values, background values from the predominant soil type near the samples were used, and it is possible the values used underrepresent the true sediment background concentration.

Since background metals concentrations vary by soil type across Culebra Island, background concentrations of metals in sediment are represented by the BTVs for the soil type most similar to sediment samples collected at the site. Beach sands were compared to the dominant soil type in the vicinity of the sample. Any detected MC in an environmental medium without background data, such as explosives, were considered COPC, and evaluated in the SLRA.

Low levels of explosives were detected at locations of three of the five background samples (Sample Locations: PR-0916-S0026 through -0030, and duplicate of PR-0916-S0030) collected from soil type Ts located within MRS 06. Therefore, the samples collected in 2011 for soil type Ts are not suitable for use as background samples. Two attempts were made to go back and confirm the explosives detections, but the location was underwater both times. No evidence of physical or historical DoD activity could be confirmed at the location where the samples were collected; the location was 200 ft from a residence. Investigation in a nearby grid found an abundance of non-munitions related debris associated with construction and residential use, but no evidence of DoD training. Impacts from non-DoD use are probable at the location where explosives were detected. The explosives detections are not attributed to DoD site use.

Alternate Ts soil type locations were identified and sampled in 2017. The 2017 results are used in this RI Report.

The soil types at sample locations collected at beaches were re-evaluated in the re-sampling effort. All beach samples except sample PR-120616-S-020-RE (which was appropriately characterized before as soil type DeE2), were changed to soil type Coastal Beach (Cm). The Cm soil type is added to Table 4-7, results tables and the Soil Source EvaluationTables in Chapter 5 were updated where applicable.

Table 4-7: Soil BTVs by Soil Type

Analyte	Units	BTV (1)(2)(3)						
		Soil Type Ts(3)	Soil Type AmC2	Soil Type Tf	Soil Type Rs(4)	Soil Type DeE2	Soil Type DrF	Soil Type Cm
Metals								
Aluminum	mg/kg	45,000	44,000	56,000	57,000	55,000	56,000	4,600
Antimony	mg/kg	0.40	0.75	0.23	1.3	1.2	0.30	0.30
Barium	mg/kg	370	1,200	670	960	710	430	20
Chromium	mg/kg	24	24	31	34	23	30	10
Copper	mg/kg	300	350	250	310	360	140	10
Lead	mg/kg	11	14	20	220	98	17	3.0
Mercury	mg/kg	0.047	0.048	0.085	0.60	0.051	0.032	0.015
Zinc	mg/kg	150	200	130	500	350	220	40

Notes:

(1) - Background concentrations determined to be twice the average concentration detected in all background soil samples of the soil type.

(2) - Five samples were collected for each soil type.

(3) - Analysis of background samples collected in MRS 06 for soil type Ts indicated the presence of explosives. Therefore, the samples collected in 2011 for soil type Ts are not suitable for use as background samples and results from relocated samples collected in 2017 are used.

(4) - Although the concentration of lead in soil type Rs is higher than the other soil types, there is a high variability of metals on the island, and the absence of explosives, and no other elevated elevated metals in the samples support that these samples do not show impacts from DoD use.

4.2.8.2 Background Concentrations for Metals in Surface Water

Three surface water samples were collected from a Cornello Lagoon in MRS 09 in an area identified from historic data as likely not impacted by DoD activities and not down gradient of DoD impacted areas. The unfiltered background surface water samples were analyzed using USEPA Methods: metals SW6020A, 7470A (mercury) and explosives 8330A. Complete analytical results for these analyses are included in Appendix C. Since explosives were not detected, the historical data of no DoD use is supported. BTVs were determined to be twice the average concentration detected in the background surface water samples. The surface water BTVs are presented in Table 4-8. Any detected MC in an environmental medium without facility-specific background data, such as explosives, were considered COPCs, and have been evaluated in the SLERA step of the baseline risk assessment.

4.2.8.3 Background Concentrations for Metals in Ground Water

No background sampling was conducted for groundwater. Groundwater results were compared to USEPA RSLs for Tap water, (Target Risk = 10-6; Hazard Quotient = 0.1), November 2013, or to a MCL if no RSL is available.

Table 4-8: Surface Water BTV

Analyte	Units	Background Threshold Value (1)
Metals		
Aluminum	µg/L	1,700
Antimony	µg/L	3.5
Barium	µg/L	360
Chromium	µg/L	3.1
Copper	µg/L	30
Lead	µg/L	0.41
Mercury	µg/L	ND
Zinc	µg/L	23

Notes: (1) -Background concentrations calculated as twice the average concentration detected in all background surface water samples.

ND – Not Detected.

4.2.8.4 Selection of PSVs

For soil, sediment, and surface water, PSVs for MC metals are selected using a two-step process: 1) first, the most conservative screening value is determined from the applicable human health and ecological screening values (Table 4-9); and 2) second, this screening value is compared to the applicable site-specific background concentration by soil type, and the greater of the two values is selected as the PSV. Explosives do not have background concentrations; therefore, screening values for explosives were determined by choosing the more conservative value between the applicable human health and ecological screening values. No back ground values are available for groundwater samples and ecological receptors are not evaluated for groundwater; therefore, the Human Health screening value is the PSV for groundwater.

PSVs for explosives are presented for soil, sediment, surface water and groundwater in Table 4-10 and Table 4-11. The contaminant-specific screening values for metals in each soil type are presented in Tables 4-12 through 4-19, the screening values for surface water for metals in Table 4-20 and for groundwater in Table 4-21. Chromium is evaluated by the following method: If screening criteria are available for chromium (III) and chromium (VI), the biased sample results for chromium (total) will be compared to the BTV prior to comparison to a screening value. If chromium (total) is detected above the BTV, then the chromium (exposure point concentration) EPC will be estimated assuming that total chromium is composed of chromium (VI) and chromium (III) in a one to six ratio. The estimated chromium (VI) concentration is calculated by dividing the measured chromium (total) concentration by seven.

Table 4-9: Background Concentrations and Risk Assessment Screening Values used for the Determination of PSVs

Media	BTV[(1)]	Human Health Screening Values	Ecological Screening Values
Soil	Twice the mean detected ambient concentrations for metals	Soil: /Sediment Soil: USEPA RSLs, Residential Soil Criteria (TR= 10^{-6} and HQ = 0.1	USEPA EcoSSLs; If USEPA EcoSSLs are unavailable, use Region 4 Ecological Screening Values (ESVs), USEPA Region 5 Ecological Screening Levels (ESLs), or Los Alamos National Laboratory (LANL) EcoRisk Database values, as appropriate.
Sediment	Twice the mean detected ambient concentrations for metals for parent soil type		USEPA Region 4 Ecological Screening Values for Sediment, November 30, 2001
Surface water	Twice the mean detected ambient concentrations for metals	PREQB WQS supplemented with USEPA RSLs Residential Tapwater Criteria; If either are unavailable, use USEPA MCLs, National Primary Drinking Water Standards	USEPA Region 4 ESVs for Freshwater Surface Water; If USEPA Region 4 ESVs are not available, use USEPA Region 5 ESVs, USEPA Region 3 Ecological Screening Benchmarks for Freshwater, or LANL Ecorisk Database values as appropriate.
Groundwater	N/A	PREQB WQSs for Class SG groundwater) supplemented with 1) USEPA Maximum Contaminant Levels (MCLs); 2) USEPA RSLs for Tapwater (TR= 10-6 and HQ = 0.1).	Not evaluated for groundwater.

(1) – Soil background concentrations of metals were established by collecting soil samples from similar soil types from locations across Culebra Island avoiding locations known to have been used for munitions activities (ambient), and surface water samples in locations upgradient from areas used for munitions activities. Background values for metals were calculated as two times the average detected ambient concentration. A 95% UCL would not be appropriate for a data set of less than 10 samples. There are no applicable background values for explosives, perchlorate, or ammonium picrate.

Table 4-10: PSVs for Explosives (Soil, Sediment, and Surface Water)

Analyte	SOIL			SEDIMENT			SURFACE WATER		
Explosives - SW8330A	Human Health Screening Values [1] (mg/kg) USEPA RSLs	Ecological Screening Values [2] (mg/kg) USEPA Eco SSLs (*unless noted*)	PSV [3] (mg/kg)	Human Health Screening Values [1] (mg/kg) USEPA RSLs	Ecological Screening Values (mg/kg) USEPA Region 4 ESVs [4] (*unless noted*)	PSV [3] (mg/kg)	Human Health Screening Values (µg/L) USEPA Tapwater RSLs [5]	Ecological Screening Values (µg/L) USEPA Region 4 ESVs [6] (*unless noted*)	PSV [3] (µg/L)
1,3,5-Trinitrobenzene	*220*	**0.38** [7]	0.38	***220***	1,300 [8]	220	***8.7***	60,000 [9]	8.7
1,3-Dinitrobenzene	***0.61***	0.66 [7]	0.61	*0.61*	**0.009** [11]	0.009	***0.15***	22 [12]	0.15
2,4,6-Trinitrotoluene	19	**6.4** [10]	6.4	19	**0.092** [14]	0.092	**2.2**	100 [15]	2.2
2,4-Dinitrotoluene	1.6	**1.3** [7]	1.3	1.6	**0.014** [11]	0.014	**0.20**	310	0.20
2,6-Dinitrotoluene	*6.1*	**0.033** [7]	0.033	*6.1*	**0.04** [11]	0.04	***1.5***	60 [9]	1.5
2-Amino-4,6-dinitrotoluene	*15*	**10** [10]	10	***15***	34 [8]	15	***3.0***	1,500 [15]	3.0
2-Nitrotoluene	**2.9**	9.9 [10]	2.9	**2.9**	28 [8]	2.9	**0.27**	39,000 [9]	0.27
3-Nitrotoluene	***0.61***	12 [10]	0.61	***0.61***	24 [8]	0.61	***0.13***	750 [15]	0.13
4-Amino-2,6-Dinitrotoluene	*15*	**3.6** [10]	3.6	*15*	**9.5** [8]	9.5	***3.0***	43,000 [9]	3.0
4-Nitrotoluene	30	**22** [10]	22	30	**4.1** [14]	4.1	**3.7**	1,900 [15]	3.7
Hexahydro-1,3,5-trinitro-1,3,5-triazine	**5.6**	7.5 [10]	5.6	5.6	**0.013** [14]	0.013	**0.61**	360 [15]	0.61
Nitrobenzene	4.8	**1.3** [7, 13]	1.3	4.8	**0.51**	0.51	**0.12**	270	0.12
Nitroglycerin	***0.61***	71 [10]	0.61	***0.61***	1,700 [8]	0.61	***0.15***	140 [15]	0.15
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	*380*	**27** [10]	27	***380***	27,000 [8]	380	***78***	150 [15]	78
PETN	120	**100** [10]	100	**120**	1,400 [8]	120	**16**	85,000 [15]	16
Methyl-2,4,6-trinitrophenylnitramine(tetryl)	*24*	**0.99** [10]	0.99	***24***	100 [8]	24	***6.3***	5,800 [9]	6.3

Notes:

(1) USEPA RSL Summary Table, residential soil, May 2012 (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/master_sl_table_run_MAY2012.pdf). Noncarcinogenic RSLs were divided by 10 to reflect a HQ of 0.1 to account for potential cumulative effects. Adjusted values are shown in *italics*.

(2) USEPA Ecological Soil Screening Levels (Eco SSL), various updates (http://www.epa.gov/ecotox/ecossl/).

(3) The PSVs for this RI were selected using a two-step process: a) first, the most conservative screening value was determined from the applicable human health screening values (USEPA RSLs) and ESVs (USEPA Eco SSLs, or Region 4, Region 5, or LANL EcoRisk Database value in the absence of a USEPA Eco SSL); b) second, this screening value was compared to the applicable soil-specific background value, and the greater of the two was selected as the PSV. The selected PSV is shown in **bold**.

(4) USEPA Region 4 Ecological Screening Values for Sediment, November 30, 2001 (http://www.epa.gov/region4/superfund/programs/riskassess/ecolbul.html#tbl3).

(5) USEPA RSL Summary Table, Tap water, May 2012 (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/master_sl_table_run_MAY2012.pdf). Noncarcinogenic RSLs were divided by 10 to reflect a HQ of 0.1 to account for potential cumulative effects. Adjusted values are shown in *italics*.

(6) USEPA Region 4 Ecological Screening Values for Freshwater Surface Water, November 30, 2001 (http://www.epa.gov/region4/superfund/programs/riskassess/ecolbul.html#tbl1).

(7) No USEPA Eco SSL available. Used USEPA Region 5 ecological screening values, August 22, 2003 (http://www.epa.gov/Region5/waste/cars/pdfs/ecological-screening-levels-200308.pdf).

(8) No USEPA Region 4 ESV for sediment available. Used Los Alamos National Laboratory, Eco Risk Database (Release 3.0), October 2011 (http://www.lanl.gov/environment/cleanup/ecorisk.shtml).

(9) No USEPA Region 4 ESV for surface water available. Used Los Alamos National Laboratory, Eco Risk Database (Release 3.0), October 2011 (http://www.lanl.gov/environment/cleanup/ecorisk.shtml).

(10) No USEPA Eco SSL available. Used Los Alamos National Laboratory, Eco Risk Database (Release 3.0), October 2011 (http://www.lanl.gov/environment/cleanup/ecorisk.shtml).

(11) No USEPA Region 4 ESV for sediment available. Used USEPA Region 5 ecological screening values, August 22, 2003 (http://www.epa.gov/Region5/waste/cars/pdfs/ecological-screening-levels-200308.pdf).

(12) No USEPA Region 4 ESV for surface water available. Used USEPA Region 5 ecological screening values, August 22, 2003 (http://www.epa.gov/Region5/waste/cars/pdfs/ecological-screening-levels-200308.pdf).

(13) No USEPA Eco SSL available. Used 1.3 mg/kg for nitrobenzene (USEPA Region 5 Ecological Screening Level) rather than the USEPA Region 4 Ecological Screening Value for soil [40mg/kg] at request of PREQB.

(14) No USEPA Region 4 ESV for sediment available. Used USEPA Region 3 Ecological Screening Benchmarks for Freshwater Sediment, March 19, 2010 (http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fwsed/screenbench.htm).

(15) No USEPA Region 4 ESV for surface water available. Used USEPA Region 3 Ecological Screening Benchmarks for Freshwater, March 19, 2010 (http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fw/screenbench.htm).

Table 4-11: PSVs for Explosives, and Ammonium Picrate (Groundwater)

Explosives - SW8330B	Human Health Screening Values (µg/L) USEPA Tapwater RSLs
1,3,5-Trinitrobenzene	46
1,3-Dinitrobenzene	0.15
2,4,6-Trinitrotoluene	0.76
2,4-Dinitrotoluene	0.20
2,6-Dinitrotoluene	0.042
2-Amino-4,6-Dinitrotoluene	3.0
2-Nitrotoluene	0.27
3-Nitrotoluene	0.13
4-Amino-2,6-Dinitrotoluene	3.0
4-Nitrotoluene	3.7
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	0.61
Nitrobenzene	0.12
Nitroglycerin	0.15
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	78
PETN	3.0
Methyl-2,4,6-trinitrophenylnitramine(tetryl)	6.1
Ammonium Picrate (8321A)	N/A

Notes:

A – USEPA RSLs for Tapwater (Target Risk = 10-6; Hazard Quotient = 0.1), May 2013. http://www.epa.gov/reg3hwmd/risk/human//rb-concentration_table/Generic_Tables/docs/master_sl_table_01run_MAY2013.pdf

Table 4-12: Preliminary Metals Screening Values for Soil for AmC2 Soil Type

Analyte	Human Health Screening Values (1) (mg/kg)	Ecological Screening Values (2) (mg/kg)	BTV (3) (mg/kg)	PSV (4) (mg/kg)
Metals - SW6020A/SW3050A	**USEPA RSLs**	**USEPA Eco SSLs (unless noted)**		
Aluminum	7,700	50 (5,6)	44,000	44,000
Barium	1,500	330	1,200	1,200
Chromium	12,000 (7)	26	24	26
Copper	310	28	350	350
Lead	400	11	14	14
Zinc	2,300	46	200	200
Antimony	3.1	0.27	0.75	0.75
Mercury	1.0 (8)	0.1 (5)	0.048	0.13

Notes:

(1) USEPA RSL Summary Table, residential soil, May 2012 (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/master_sl_table_run_MAY2012.pdf). When appropriate, noncarcinogenic RSLs were divided by 10 to reflect a HQ of 0.1 to account for potential cumulative effects. Adjusted values are shown in *italics*.

(2) USEPA Ecological Soil Screening Levels, various updates (http://www.epa.gov/ecotox/ecossl/).

(3) The background values are two times the mean concentrations detected in the background samples collected from soil type AmC2 (see Table 4-7).

(4) The PSVs for this RI were selected using a two-step process: a) first, the most conservative screening value was determined from the applicable human health screening values (USEPA RSLs) and ESVs (USEPA Eco SSLs, or Region 4, Region 5, or LANL Eco Risk Database value in the absence of a USEPA Eco SSL); b) second, this screening value was compared to the applicable soil-specific background value, and the greater of the two was selected as the PSV. The selected PSVs are shown in **bold** where applicable.

(5) No USEPA Eco SSL available. Used USEPA Region 4 Ecological Screening Values for Soil (http://www.epa.gov/region4/superfund/images/allprogrammedia/pdfs/tsstablesoilvalues.pdf).

(6) ESV for aluminum is only applicable when the pH is extremely low (less than 5.5).

(7) Value is for Chromium III.

(8) Value is for Elemental Mercury, consistent with Worksheet #15 of the RI/FS Quality Assurance Project Plan.

Table 4-13: Preliminary Metals Screening Values for Soil for Tf Soil Type

	Human Health Screening Values [1]	Ecological Screening Values[2]	BTV [3]	PSV [4]
Analyte	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**
Metals - SW6020A/SW3050A	**USEPA RSLs**	**USEPA Eco SSLs (unless noted)**		
Aluminum	7,700	50 [5,6]	**56,000**	56,000
Barium	1,500	330	**670**	670
Chromium	12,000 [7]	26	**31**	31
Copper	310	28	**250**	250
Lead	400	11	**20**	20
Zinc	2,300	46	**130**	130
Antimony	3.1	**0.27**	0.23	0.27
Mercury	1.0 [8]	**0.1** [5]	0.085	0.13

Notes:

(1) USEPA RSL Summary Table, residential soil, May 2012 (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/master_sl_table_run_MAY2012.pdf). As appropriate, noncarcinogenic RSLs were divided by 10 to reflect a HQ of 0.1 to account for potential cumulative effects. Adjusted values are shown in *italics*.

(2) USEPA Ecological Soil Screening Levels, various updates (http://www.epa.gov/ecotox/ecossl/).

(3) The background values are two times the mean concentrations detected in the background samples collected from soil type Tf (see Table 4-7).

(4) The PSVs for this RI were selected using a two-step process: a) first, the most conservative screening value was determined from the applicable human health screening values (USEPA RSLs) and ESVs (USEPA Eco SSLs, or Region 4, Region 5, or LANL Eco Risk Database value in the absence of a USEPA Eco SSL); b) second, this screening value was compared to the applicable soil-specific background value, and the greater of the two was selected as the PSV. The selected PSV are shown in bold where applicable.

(5) No USEPA Eco SSL available. Used USEPA Region 4 Ecological Screening Values for Soil (http://www.epa.gov/region4/superfund/images/allprogrammedia/pdfs/tsstablesoilvalues.pdf).

(6) ESV for aluminum is only applicable when the pH is extremely low (less than 5.5).

(7) Value is for Chromium III.

(8) Value is for Elemental Mercury, consistent with Worksheet #15 of the RI/FS QAPP.

Table 4-14: Preliminary Metals Screening Values for Soil for Rs Soil Type

	Human Health Screening Values [1]	Ecological Screening Values[2]	BTV [3]	PSV[4]
Analyte	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**
Metals - SW6020A/SW3050A	**USEPA RSLs**	**USEPA Eco SSLs (*unless noted*)**		
Aluminum	7,700	50 [5,6]	**57,000**	57,000
Barium	1,500	330	**960**	960
Chromium	12,000 [7]	26	**34**	34
Copper	310	28	**310**	310
Lead	400	11	**220**	220
Zinc	2,300	46	**500**	500
Antimony	3.1	0.27	**1.3**	1.3
Mercury	1.0 [8]	0.1[5]	**0.60**	0.60

Notes:

(1) USEPA RSL Summary Table, residential soil, May 2012 (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/master_sl_table_run_MAY2012.pdf). As appropriate, noncarcinogenic RSLs were divided by 10 to reflect a HQ of 0.1 to account for potential cumulative effects. Adjusted values are shown in *italics*.

(2) USEPA Ecological Soil Screening Levels, various updates (http://www.epa.gov/ecotox/ecossl/).

(3) The background values are two times the mean concentrations detected in the background samples collected from soil type Rs (see Table 4-7).

(4) The PSVs for this RI were selected using a two-step process: a) first, the most conservative screening value was determined from the applicable human health screening values (USEPA RSLs) and ESVs (USEPA Eco SSLs, or Region 4, Region 5, or LANL Eco Risk Database value in the absence of a USEPA Eco SSL); b) second, this screening value was compared to the applicable soil-specific background value, and the greater of the two was selected as the PSV. The selected PSVs are shown in bold where applicable.

(5) No USEPA EcoSSL available. Used USEPA Region 4 Ecological Screening Values for Soil (http://www.epa.gov/region4/superfund/images/allprogrammedia/pdfs/tsstablesoilvalues.pdf).

(6) ESV for aluminum is only applicable when the pH is extremely low (less than 5.5).

(7) Value is for Chromium III.

(8) Value is for Elemental Mercury, consistent with Worksheet #15 of the RI/FS Quality Assurance Project Plan.

Table 4-15: Preliminary Metals Screening Values for Soil for DeE2 Soil Type

	Human Health Screening Values (1)	Ecological Screening Values(2)	BTV (3)	PSV(4)
Analyte	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**
Metals - SW6020A/SW3050A	**USEPA RSLs**	**USEPA Eco SSLs (*unless noted*)**		
Aluminum	7,700	50 (5,6)	**55,000**	55,000
Barium	1,500	330	**710**	710
Chromium	12,000 (7)	**26**	23	26
Copper	310	28	**360**	360
Lead	400	11	**98**	98
Zinc	2,300	46	**350**	350
Antimony	3.1	0.27	**1.2**	1.2
Mercury	1.0 (8)	**0.1 (5)**	0.051	0.13

Notes:

(1) USEPA RSL Summary Table, residential soil, May 2012 (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/master_sl_table_run_MAY2012.pdf). As appropriate, noncarcinogenic RSLs were divided by 10 to reflect a HQ of 0.1 to account for potential cumulative effects. Adjusted values are shown in *italics*.

(2) USEPA Ecological Soil Screening Levels, various updates (http://www.epa.gov/ecotox/ecossl/).

(3) The background values are two times the mean concentrations detected in the background samples collected from soil type DeE2 (see Table 4-7).

(4) The PSVs for this RI were selected using a two-step process: a) first, the most conservative screening value was determined from the applicable human health screening values (USEPA RSLs) and ESVs (USEPA Eco SSLs, or Region 4, Region 5, or LANL Eco Risk Database value in the absence of a USEPA Eco SSL); b) second, this screening value was compared to the applicable soil-specific background value, and the greater of the two was selected as the PSV. The selected PSV are shown in bold where applicable.

(5) No USEPA EcoSSL available. Used USEPA Region 4 Ecological Screening Values for Soil (http://www.epa.gov/region4/superfund/images/allprogrammedia/pdfs/tsstablesoilvalues.pdf).

(6) ESV for aluminum is only applicable when the pH is extremely low (less than 5.5).

(7) Value is for Chromium III.

(8) Value is for Elemental Mercury, consistent with Worksheet #15 of the RI/FS QAPP.

Table 4-16: Preliminary Metals Screening Values for Soil for DrF Soil Type

	Human Health Screening Values [1]	Ecological Screening Values[2]	BTV [3]	PSV[4]
Analyte	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**
Metals - SW6020A/SW3050A	**USEPA RSLs**	**USEPA Eco SSLs (*unless noted*)**		
Aluminum	7,700	50 [5,6]	**56,000**	56,000
Barium	1,500	330	**430**	430
Chromium	12,000 [7]	26	**30**	30
Copper	310	28	**140**	140
Lead	400	11	**17**	17
Zinc	2,300	46	**220**	220
Antimony	3.1	0.27	**0.30**	0.30
Mercury	1.0 [8]	**0.1** [5]	0.032	0.13

Notes:

(1) USEPA RSL Summary Table, residential soil, May 2012 (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/master_sl_table_run_MAY2012.pdf). As appropriate, noncarcinogenic RSLs were divided by 10 to reflect a HQ of 0.1 to account for potential cumulative effects. Adjusted values are shown in *italics*.

(2) USEPA Ecological Soil Screening Levels, various updates (http://www.epa.gov/ecotox/ecossl/).

(3) The background values are two times the mean concentrations detected in the background samples collected from soil type DrF (see Table 4-7).

(4) The PSVs for this RI were selected using a two-step process: a) first, the most conservative screening value was determined from the applicable human health screening values (USEPA RSLs) and ESVs (USEPA Eco SSLs, or Region 4, Region 5, or LANL Eco Risk Database value in the absence of a USEPA Eco SSL); b) second, this screening value was compared to the applicable soil-specific background value, and the greater of the two was selected as the PSV. The selected PSVs are shown in **bold** where applicable.

(5) No USEPA EcoSSL available. Used USEPA Region 4 Ecological Screening Values for Soil (http://www.epa.gov/region4/superfund/images/allprogrammedia/pdfs/tsstablesoilvalues.pdf).

(6) ESV for aluminum is only applicable when the pH is extremely low (less than 5.5).

(7) Value is for Chromium III.

(8) Value is for Elemental Mercury, consistent with Worksheet #15 of the RI/FS QAPP.

Table 4-17: Preliminary Metals Screening Values for Soil for Ts Soil Type

	Human Health Screening Values [1]	Ecological Screening Values[2]	BTV [3]	PSV [4]
Analyte	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**
Metals - SW6020A/SW3050A	**USEPA RSLs**	**USEPA Eco SSLs (*unless noted*)**		
Aluminum	7,700	**50** [5,6]	45,000	45,000
Barium	1,500	330	**370**	370
Chromium	12,000 [7]	**26**	24	26
Copper	310	28	**300**	300
Lead	400	**11**	11	11
Zinc	2,300	46	**150**	150
Antimony	3.1	**0.27**	0.40	0.40
Mercury	1.0 [8]	**0.10** [5]	0.047	0.10

Notes:

(1) USEPA RSL Summary Table, residential soil, May 2012 (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/master_sl_table_run_MAY2012.pdf). As appropriate, noncarcinogenic RSLs were divided by 10 to reflect a HQ of 0.1 to account for potential cumulative effects. Adjusted values are shown in *italics*.

(2) USEPA Ecological Soil Screening Levels, various updates (http://www.epa.gov/ecotox/ecossl/).

(3) Background samples collected in 2011 for soil type Ts indicated detections of explosives at 3 locations which disqualified the samples for background use. The samples for Ts soil type were relocated and the 2017 results are reported here. PSV updated will new results. The background values are two times the mean concentrations detected in the background samples collected from soil type Ts (see Table 4-7).

(4) The PSVs for this RI were selected using a two-step process: a) first, the most conservative screening value was determined from the applicable human health screening values (USEPA RSLs) and ESVs (USEPA Eco SSLs, or Region 4, Region 5, or LANL EcoRisk Database value in the absence of a USEPA Eco SSL); b) second, this screening value was compared to the applicable soil-specific background value, and the greater of the two was selected as the PSV. The selected PSVs are shown in **bold** where applicable.

(5) No USEPA EcoSSL available. Used USEPA Region 4 Ecological Screening Values for Soil (http://www.epa.gov/region4/superfund/images/allprogrammedia/pdfs/tsstablesoilvalues.pdf).

(6) ESV for aluminum is only applicable when the pH is extremely low (less than 5.5).

(7) Value is for Chromium III.

(8) Value is for Elemental Mercury, consistent with Worksheet #15 of the RI/FS QAPP.

Table 4-18: Preliminary Metals Screening Values for Sediment for Rs Soil Type

	Human Health Screening Values (1)	Ecological Screening Values(2)	BTV (3)	PSV(4)
Analyte	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**
Metals - SW6020A/SW3050A	**USEPA RSLs**	**USEPA Region 4 ESVs (*unless noted*)**		
Aluminum	7,700	280 (5)	**57,000**	57,000
Barium	1,500	48 (5)	**960**	960
Chromium	12,000 (7)	**52**	34	52
Copper	310	19	**310**	310
Lead	400	30	**220**	220
Zinc	2,300	120	**500**	500
Antimony	**3.1**	12	1.3	3.1
Mercury	1.0 (7)	0.1	**0.60**	0.60

Notes:

(1) USEPA RSL Summary Table, residential soil, May 2012 (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/master_sl_table_run_MAY2012.pdf). As appropriate, noncarcinogenic RSLs were divided by 10 to reflect a HQ of 0.1 to account for potential cumulative effects. Adjusted values are shown in *italics*.

(2) USEPA Region 4 Ecological Screening Values for Sediment, November 30, 2001 (http://www.epa.gov/region4/superfund/programs/riskassess/ecolbul html#tbl3).

(3) The background values are two times the mean concentrations detected in the background samples collected from soil type Rs (see Table 4-7).

(4) The PSVs for this RI were selected using a two-step process: a) first, the most conservative screening value was determined from the applicable human health screening values (USEPA RSLs) and ESVs (USEPA Region 4 ESVs, or Region 5, or, Region 3, or LANL Eco Risk Database value in the absence of a USEPA Region 4 ESVs); b) second, this screening value was compared to the applicable soil-specific background value, and the greater of the two was selected as the PSV. The selected PSV are shown in bold where applicable.

(5) No USEPA Region 4 ESV for Sediment available. Used Los Alamos National Laboratory, Eco Risk Database (Release 3.0), October 2011 (http://www.lanl.gov/environment/cleanup/ecorisk.shtml).

(6) Value is for Chromium III.

(7) Value is for Elemental Mercury, consistent with Worksheet #15 of the RI/FS QAPP.

Table 4-19: Preliminary Metals Screening Values for Soil for Cm Soil Type

	Human Health Screening Values [1]	Ecological Screening Values[2]	BTV [3]	PSV[4]
Analyte	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**	**(mg/kg)**
Metals - SW6020A/SW3050A	**USEPA RSLs**	**USEPA Region 4 ESVs (*unless noted*)**		
Aluminum	7,700	280 [5]	**4,600**	4,600
Barium	1,500	**48** [5]	16	48
Chromium	12,000 [7]	**52**	12	52
Copper	310	**19**	10	19
Lead	400	**30**	3.2	30
Zinc	2,300	**120**	42	120
Antimony	**3.1**	12	0.3	3.1
Mercury	1.0 [7]	0.10	0.015	0.10

Notes:

(1) USEPA RSL Summary Table, residential soil, May 2012 (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/master_sl_table_run_MAY2012.pdf). As appropriate, noncarcinogenic RSLs were divided by 10 to reflect a HQ of 0.1 to account for potential cumulative effects. Adjusted values are shown in *italics*.

(2) USEPA Region 4 Ecological Screening Values for Sediment, November 30, 2001 (http://www.epa.gov/region4/superfund/programs/riskassess/ecolbul html#tbl3).

(3) The background values are two times the mean concentrations detected in the background samples collected from soil type Cm (see Table 4-7).

(4) The PSVs for this RI were selected using a two-step process: a) first, the most conservative screening value was determined from the applicable human health screening values (USEPA RSLs) and ESVs (USEPA Region 4 ESVs, or Region 5, or, Region 3, or LANL Eco Risk Database value in the absence of a USEPA Region 4 ESVs); b) second, this screening value was compared to the applicable soil-specific background value, and the greater of the two was selected as the PSV. The selected PSV are shown in bold where applicable.

(5) No USEPA Region 4 ESV for Sediment available. Used Los Alamos National Laboratory, Eco Risk Database (Release 3.0), October 2011 (http://www.lanl.gov/environment/cleanup/ecorisk.shtml).

(6) Value is for Chromium III.

(7) Value is for Elemental Mercury, consistent with Worksheet #15 of the RI/FS QAPP.

Table 4-20: Preliminary Metals Screening Values for Surface Water

	As Noted	Human Health Screening Values (2)	Ecological Screening Values(3)	BTV (4)	PSV (5)
Analyte	**(µg/L)**	**(µg/L)**	**(µg/L)**	**(µg/L)**	**(µg/L)**
Metals - SW6020A/SW3020A	**PREQB WQS(1)**	**USEPA RSLs**	**USEPA Region 4 ESVs (*unless noted*)**		
Aluminum	NA	1,600	87	**1,700**	1,700
Barium	NA	290	220 (6)	**360**	360
Chromium	NA	1,600 (7)	**120**	3.1	120
Copper	3.73 (AL)	61	6.5	**30**	30
Lead	8.52 (AL)	15 (8)	**1.3**	0.41	1.3
Zinc	85.62 (AL)	470	**59**	23	59
Antimony	640 (HH)	0.60	160	**3.5**	3.5
Mercury (7470A)	.051(HH)	0.063 (9)	**0.012**	ND	0.01

Notes:

(1) PREQB WQSs for Class SB surface water, March 2010. HH = Human Health; AL=Aquatic Life

(2) USEPA RSL Summary Table, Tap water, May 2012 (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/master_sl_table_run_MAY2012.pdf). As appropriate, noncarcinogenic RSLs were divided by 10 to reflect a HQ of 0.1 to account for potential cumulative effects. Adjusted values are shown in *italics*.

(3) USEPA Region 4 Ecological Screening Values for Freshwater Surface Water, November 30, 2001 (http://www.epa.gov/region4/superfund/programs/riskassess/ecolbul html#tbl1).

(4) The background values are two times the mean concentrations detected in the background samples collected (Table 4-8).

(5) The PSVs for this RI were selected using a two-step process: a) first, the most conservative screening value was determined from the applicable human health screening values PREQB WQS (USEPA RSLs) and ESVs (USEPA Region 4 ESVs, or Region 5, or, Region 3, or LANL Eco Risk Database value in the absence of a USEPA Eco Region 4 ESVs); b) second, this screening value was compared to the applicable surface water background value, and the greater of the two was selected as the PSV. The selected PSVs are shown in **bold** where applicable.

(6) No USEPA Region 4 ESV available. Used USEPA Region 5 ecological screening values, August 22, 2003 (http://www.epa.gov/Region5/waste/cars/pdfs/ecological-screening-levels-200308.pdf).

(7) Value is for Chromium III.

(8) No USEPA RSL available. Used USEPA MCLs, National Primary Drinking Water Standards, May 4, 2011 (http://www.epa.gov/safewater/contaminants/index html).

(9) Value is for Elemental Mercury, consistent with Worksheet #15 of the RI/FS QAPP. ND = Not detected

Table 4-21: Preliminary Metals Screening Values for Ground Water

	Human Health Screening Values[1]	Human Health Screening Values [2]	PSV
Analyte	**(µg/L)**	**(µg/L)**	
Metals - SW6020A/7470A	**PREQB WQSs**	**USEPA RSLs (unless otherwise noted)**	
Aluminum	NA	1,600	1,600
Antimony	5.6	0.60	5.6
Barium	NA	290	290
Chromium (Total) [3]	100	N/A	100
Chromium(III)	NA	1,600	1,600
Chromium(VI)	NA	0.031	0.031
Copper	NA	62	62
Lead	15	15 [4]	15
Mercury [5]	.050	0.43	0.05
Zinc	NA	470	470
Perchlorate (6850)	NA	1.1	1.1

N/A – Not Applicable

(1) PREQB WQSs for Class SB surface water, March 2010.

(2) USEPA RSLs for Tapwater (Target Risk = 10-6; Hazard Quotient = 0.1), November 2013. (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/docs/master_sl_table_01run_NOV2013.pdf)

(3) Chromium can exist in the environment as chromium (III) and chromium (VI). Analytical results are for chromium (total) and do not distinguish between the different valence states. However, screening criteria are available for chromium (III) and chromium (VI), so the chromium concentrations will be estimated assuming that total chromium is composed of chromium (VI) and chromium (III) in a one to six ratio. The estimated chromium (VI) concentration is calculated by dividing the maximum chromium (total) concentration measured in soil samples by seven. The estimated chromium (III) concentration is the difference of the maximum chromium (total) concentration and the estimated chromium (VI) concentration.

(4) USEPA RSL not established. Used USEPA Maximum Contaminant Level. (http://www.epa.gov/reg3hwmd/risk/human//rb-concentration_table/Generic_Tables/docs/master_sl_table_01run_November2013.pdf)

(5) Used mercuric chloride.

CHAPTER 5. REVISED CSM AND RI RESULTS

5.1 INTRODUCTION

RI MEC activities were conducted at the Culebra Island MRSs from May 2008 through October 2011. MC sampling continued into February 2012, with re-sampling events in December 2016 and February 2017. A groundwater well survey was conducted in September 2013, and well installation and groundwater sampling were conducted in December 2013. Investigative work consisted of DGM, intrusive investigation of geophysical anomalies, intrusive investigation using handheld metal detectors (analog mag-and-dig), and sampling and analysis for MC. Findings from a 2009 Post Award site visit are included to augment the RI MEC investigation results in MRS 13. The results of the geophysical/intrusive investigations and MC sampling are detailed below.

5.2 RI RESULTS

As described in Chapter 4, the RI involved excavation of anomalies selected from DGM data and anomalies identified using handheld metal detectors (analog mag-and-dig) as well as MC sample collection. This section provides a summary of the distribution of MEC, MD, and MC identified from the intrusive investigations. This distribution is evaluated in terms of the historical information related to the munitions demonstrations and munitions-related training that was conducted at the site. This information is, in turn, used to revise the pre-RI CSM that was presented in Chapter 3.

5.3 MEC AND MD

DGM data was collected along upland area transects, and within grids placed in high anomaly density areas. Analog mag-and-dig investigations were used to investigate accessible beach areas and selected trails on MRS 13. The results of the excavation of anomalies, both DGM and analog mag-and-dig, are presented in Table 4-2. During vegetation removal, two MPPEH items were found on the surface at two locations in MRS 09: two Mk 25 Marine Markers. These marine markers were recovered on the surface along transects and not in the intrusive investigation grids, but are included in the results as were shown in Table 4-2. The table presents the number of locations for various data categories. MPPEH and MD finds represent a very small proportion of the locations investigated. Small arms ammunition is evaluated separately from other MD because they do not represent the same level of hazard. Some locations had multiple MD and non-MD. For MD, the precise number of items at a particular location is not always countable due to the fact that these items are often in pieces. Appendix A: Figures A-31 through A-36 show the distribution of the intrusive investigation results for each Culebra Island MRS. The following paragraphs provide a summary of the MD items recovered from each MRS. Appendix H contains tabulated intrusive results for each MRS.

5.3.1 MRS 06 Artillery Firing Area

MRS 06 was used by the U. S. Marines for artillery firing points during exercises conducted between 1922 and the 1940s. Appendix A: Figure A-31 reflects the intrusive results for MRS 06, as shown on Table 4-2. Due to the lack of ROE, transects and grids were located as close as possible so as to be representative of the area, but still achieving the acreage needed to meet the investigation requirements per the PWS (EM-1110-1-4009, Chapter 7, Site Characterization). Only four (4) MD items were recovered in MRS 06 (Grids 06-03, 06-07 and 06-17). The two items were identified as: one fragment in which the munition type could not be determined and the second MD item is believed to be a portion of a rotating band which is indicative of a projectile; however, neither the munition size nor the nomenclature was determined due to the small size of the fragment. These two items were recovered in two separate grids (Grids 06-03 and 06-17). Grid 06-03 is located adjacent to residential development, which could be a source for the metallic fragment recovered; however, since this could not be confirmed as the source, it has been assumed to be MD. No impact areas are historically documented near Grid 06-03. Grid 06-17 is located within the historical buffer areas of Cayo Botella, an adjacent target island located approximately 2,000 yards to the northeast of MRS 06, suggesting a potential source of MD fragments. The other two MD items were identified as artillery primers and were recovered from the same grid (Grid 06-07). The location Grid 06-07 does not correlate to historical maneuver or firing point area as shown on the ASR Supplement (USACE 2005). No MEC or MD items were recovered along the beach areas of MRS 06.

No target remnants, physical evidence, high density anomaly areas indicating a target area, or DoD munitions use was discovered in MRS 6 other than the four MD items mentioned above. A post-VSP analysis was used to determine if there were any data gaps in MRS 06, consistent with potential CMUAs or target impact areas. During the RI, no target areas were discovered; thus, munitions suspected to have impacted neighboring MRS's were used (4.2 inch mortar and 75mm projectile) in the VSP analysis to determine whether the completed investigation resulted in significant data gaps and to identify the locations for the data gaps. The post-VSP analysis results determined there were no RI data gaps for MRS 06, consistent with potential CMUAs or Target Impact areas.

The results of the underwater ROV visual transects for MRS 06 produced no indications of DoD munitions use, MEC/MD, or target debris.

The two expended artillery primers found in Grid 6-7 are believed to have originated in MRS 06 but there was no other discoveries in Grid 6-7 to indicate a burial pit, DMM or other indications of a firing point that may require additional investigation or removal actions in the future. The low density of the recovered MD in MRS 06 is not indicative of these areas being used as target or impact areas. There is no historical evidence of MEC discoveries in MRS 06. Isolated pieces of munitions fragments may be in the MRS originating from munitions that detonated some distance away and outside of the MRS boundary, so their presence does not necessarily indicate a significant hazard.

5.3.2 MRS 08 Cayo Norte Impact Area

MRS 08 was leased by the Marines for 75 mm artillery practice. However, it had not been determined from records whether the site was ever used for training.

Appendix A: Figure A-32 reflects the intrusive results for MRS 08 as shown in Table 4-3. Thirteen MD items were recovered in six grids within MRS 08 (Grids 08-02, 08-03, 08-06, 08-07, 08-08, and 08-09). All 13 MD items were identified to be fragmentation from 75 mm projectiles and are consistent with historical records. Although the anomaly density on MRS 08 is relatively low, there are sufficient amounts of MD to confirm the western side of MRS 08 was used as 75 mm artillery target area, even if for a short period of time. No MEC or MD items were recovered along the beach areas of MRS 08. The results of the underwater ROV visual transects for MRS 08 produced no indications of DoD munitions use, MEC/MD, or target debris. The presence of MD in the upland areas indicates the possibility of an explosive hazard to be present in MRS 08.

5.3.3 MRS 09 Soldado Point Mortar and Bombing Area

Several training exercises including mortar firing, aerial bombing, and strafing were conducted within MRS 09 during the 1930s and 1940s. Appendix A: Figure A-33 reflects the intrusive results for MRS 09 as shown in Table 4-3. Seven MD items were recovered in three grids (09-04, 09-07, and 09-13) within MRS 09. No MEC or MD items were recovered along the beach areas of MRS 09. Two Mk 25 Marine Markers were recovered along the surface along the DGM transects located close to the coves as earlier described in Section 1 of this report. The Mk 25 Marine Markers had been functioned and are considered incidental to the site; they were treated as MEC since the interior of the Marine Markers could not be fully inspected even though they were expended. MD recovered from the grid corresponds to 3-inch naval projectiles and 4.2–inch mortar use; however, no MD was recovered that indicated aerial bombing use within MRS 09. Historical documentation indicated use of upland areas for 4.2-inch mortar impact areas. The bombing targets were historically documented as being located within the water areas of Sueño Cove. The results of the underwater ROV visual transects for MRS 09 produced no indications of DoD munitions use, MEC/MD, or target debris. The presence of MEC and MD in the upland areas indicates the possibility for an explosive hazard to be present in MRS 09.

5.3.4 MRS 10 Defensive Firing Area No. 1

Appendix A: Figure A-34 shows the areas investigated within MRS 10. Marines conducted amphibious landing and ground maneuver training using 81mm mortars on the beaches and hills in this area from the 1920s through the 1940s. Specifically, the hill on the north end of the MRS has been listed as a 1935 area of direct fire from 3-inch projectiles, and Snug Bay was shown as a 1935 water area for direct fire. Additionally, a 1924 outpost and ammunition storage area was located on the north end of the MRS. No MEC or MD items were recovered within the upland grids or along the beach areas of MRS 10. Intrusive investigations yielded mostly hot rocks or other debris such as fencing, nails, cans, and other non-munitions related debris. The results of the underwater ROV visual transects for MRS 10 produced no indications of DoD munitions use, MEC/MD, or target debris. The absence of MEC and MD within the investigation areas indicates that historical munitions use, if any, was very limited. Therefore, the anticipated explosive hazard present in MRS 10 is not significant, based on historical findings and no RI MEC/MD findings.

5.3.5 MRS 11 DEFENSIVE FIRING AREA NO. 2

Several training exercises were historically documented in MRS 11, including 75mm and 155mm firing from Firewood Bay at Mono Cay (part of MRS 02) and portions of Cayo de Luis Peña (MRS 13) in 1924; firing of small arms and 81mm mortars in 1936; and in boat-to-beach firing of 5-inch and 6-inch projectiles in 1941. The northern portion of MRS 11 is adjacent to the NWP bombardment area, which was the main target area on Culebra. Appendix A: Figure A-35 reflects the intrusive results for MRS 11 as shown in Table 4-3. Fifteen MD items were recovered from the upland grids (11-13, 11-14, 11-15, 11-16, and 11-17) and two MD items were recovered from beach transects (11M-08 and 11M-11). All of the upland grids containing MD are located within the northern portion of the MRS, which is directly adjacent to the NWP bombardment area. MD from these grids were identified as heavy cased munition fragments, which are indicative of the munitions fired at targets located within the NWP bombardment area. The two MD items located within the beach areas were identified as being an empty 5-inch projectile and a partial BDU-33 practice bomb. The proximity of the beach areas to the NWP bombardment area are also consistent with the type of MD recovered. There is no historical evidence of waterborne targets in the near-shore acres of MRS 11. The results of the underwater ROV visual transects conducted within the Mosquito Bay side of MRS 11 produced no indications of DoD munitions use, MEC/MD, or target debris. The coastal waters of the west side of MRS 11 were also investigated via visual transects and produced one item of interest that may be munitions related. The item is directly south of the MRS 12 underwater boundary. The southern portion of MRS 12, as it lies adjacent to MRS 11, was also investigated as part of this underwater visual investigation for MRS 11 and no indications of DoD munitions use, MEC/MD, or target debris were discovered.

The presence of MD in the northern investigation grids and beach areas indicate the possibility for an explosive hazard to be present in the northern portion of MRS 11. However, no MEC or MD items were recovered within the southern portions of MRS 11, as shown in Appendix A: Figure A-35. The absence of MEC and MD within the southern investigation areas indicates that historical munitions use, if any, was very limited. Therefore, the anticipated explosive hazard present in the southern portions of MRS 11 is not significant, based on the amount of historical and RI MEC/MD findings.

5.3.6 MRS 13 Cayo Luis Peña Impact Areas

Several training exercises were historically documented in MRS 13. The northern tip of this island was used as a firing target during Marine exercises conducted between 1924 and 1941. Records show that 75mm projectiles were fired at the northern tip of MRS 13 in 1924 and that 155mm, 37mm, 8-inch, and 6-inch projectiles may have also been used. In the 1960s, an observation point was erected on the hilltop on Luis Peña, including a run-in line, helipad, and living quarters. A TPP decision was made to not conduct vegetation removal in order to conduct DGM surveys on MRS 13; therefore, the RI investigations conducted on MRS 13 were limited to analog mag-and-dig investigations along established trails and within the beach areas. The beach areas identified during the TPP Meetings for investigation were believed to be accessible by recreational users and these areas were investigated per the WP. Beach areas were not planned/selected for investigation if they did not allow for easy public access due to the shallow coral reef that would impede access from the water, or if the area consisted of a steep/rocky shorelines. The investigation in this MRS is augmented with visual surface reconnaissance from

a 2009 post award site visit. Appendix A: Figure A-36 reflects the RI intrusive results for MRS 13, as shown in Table 4-3. The RI recovered ten MD items and two MD items from expended small arms ammunition were recovered on MRS 13 beach areas. A majority of these items were recovered on the northern portion of MRS 13. During the 2009 site visit, there were observations of MD from 105mm projectiles (1-HE, 1-illumination, 4-unidentified), 5-inch projectiles (31), 3-inch projectiles (3), flares (8), fuzes, and other MD pieces. The northern area of MRS 13 is located behind the range fans associated with the NWP bombardment area, thus having the possibility of receiving overshoots from that range (3-inch to 8-inch projectiles). The majority of MD recovered in this area consisted of empty 5-inch illumination projectiles. These items are consistent with the types of naval gunnery practice conducted within the NWP bombardment area.

The ASR Supplement (USACE, 2005) shows the northern tip of MRS 13 as a 1924 75mm and 155mm target area. This area is inaccessible due to extremely steep terrain and heavy vegetation; thus, no RI investigations were conducted within this area. In addition, MD related to 75mm or 155mm use was not recovered around the adjacent beach areas. One partial BDU-33 practice bomb was recovered in one of the digs on beach transect 13M-13. The beach in which this was recovered is within the run-in line for a bombing target located on Agua Cay, located to the northwest of this beach area. It is believed that the recovered BDU-33 may be a short that was dropped on MRS 13. The results of the underwater ROV visual transects for MRS 13 produced 39 items that were either suspect MEC items or items that had the appearance or shape of munitions, munition remnants, or MD. The presence of MD indicates the possibility of an explosive hazard to be present in MRS 13.

5.4 MC

As outlined in the RI WP, a phased baseline risk assessment approach was employed starting with the evaluation and identification of preliminary contaminants of potential concern (PCOPCs) for each site to determine COPCs that would then be evaluated further. To determine if a PCOPC should be considered a COPC, each PCOPC was evaluated using several criteria. For an analyte to be considered contamination related to a release from munitions-related activities at the site (i.e., COPC), it is necessary for the following conditions to be true.

- The analyte is detected in the sample medium.
- The analyte is a potential constituent of the munitions formerly used at the site.
- The analyte is present at concentrations greater than the selected PSVs.

Each PCOPC was evaluated using these criteria to determine whether or not potential contamination is present at the site. The maximum detected concentrations of analytes at each site were compared to PSVs in the Source Evaluation Tables (see Chapter 7). Only PCOPCs that met the conditions noted above were considered COPCs and were evaluated further in the risk assessment. Tables containing the laboratory analytical results are presented in Appendix C of this document. The analytical results for the individual sites are evaluated separately.

5.4.1 MC Characterization Data

An evaluation of the analytical data for each MRS at Culebra Island site used to characterize the presence of MC in environmental media is presented in the following sections. The evaluation

determined whether there was evidence of a release of contaminants at each MRS and identified COPCs requiring further consideration in the risk assessment process. No MC samples were collected in MRS 10 since no MEC or MD was recovered during the intrusive investigations. Therefore no MC Characterization activities were conducted in MRS 10.

5.4.1.1 MRS 06 North

Surface Soil

In support of the RI, one surface soil sample (PR-1014-S-084) was collected within DeE2 soils at MRS 06N and analyzed for explosives and eight MC metals. Following evaluation of this initial sample, an additional 13 step-out samples (PR-0212-S-001 through PR-0212-S-013 plus one duplicate) were collected surrounding this sample location to further evaluate and characterize the potential release of barium to surface soil at this location. The step-out samples were analyzed for barium only. The step-out samples also exceeded the barium PSV at five locations to the east and southeast of the original sample. The need for further sampling will be evaluated in the risk assessment based on the magnitude of the exceedance in relation to the soil specific background value and naturally occurring values on the island.

Explosives were detected at locations of three of the five background samples collected from soil type Ts (Sample Location 6: PR-0916-S0026 through -0030, and duplicate of PR-0916-S0030), collected from within MRS 06N. Therefore, the samples collected in 2011 for soil type Ts are not suitable for use as background samples and were relocated; results from the relocated samples are used in this RI Report. No evidence of physical or historical DoD activity could be confirmed at the location where the original samples were collected. The samples were collected less than 200 ft from a residence. Investigation in a nearby grid found an abundance of non-munitions related debris associated with construction and residential use, but no evidence of DoD training. Impacts from non-DoD use are probable at the location where explosives were detected. Since the samples are not investigative samples per the DQOs of the RI, and none of the detections are considered COPCs, they are not considered part of this RI.

The analytical results are presented in Appendix C.

The maximum detected concentration of each analyte detected in surface soil is compared to PSVs in Table 5-1. The maximum detected concentration of barium (1,100 mg/kg) was greater than the PSVs (710 mg/kg); therefore, barium is considered a COPC and is retained for further consideration.

Surface Water and Sediment

One lagoon located in the northern portion of MRS 06 exists within a property in which ROE was refused (see Appendix A: Figure A-31). Although lack of access to the surface water and sediment prevented sampling, investigation in nearby parcels indicated no evidence of MEC, and no evidence of high concentrations of MD. Sampling is not necessary to characterize the lagoon. The lack of a source indicates MC contamination is improbable in the surface water and sediment. Therefore surface water and sediment were not evaluated in the RI.

Groundwater

To evaluate the potential risk attributable to MC associated with groundwater in the northern portion of MRS 06, one groundwater sample (PR-CUL-GW-MRS-06-6) was collected from an existing well identified as Well 6-6 (Appendix A: Figure A-21) and analyzed for explosives, ammonium picrate, eight MC metals, perchlorate, chloride, and nitrate/nitrite as N. This is a large-diameter well, under the control of the owner by means of a lock, and is currently in use for irrigation purposes. Because the well was in use for irrigation purposes, it was sampled; due to the large diameter it may not be representative of true groundwater conditions. However, no MEC or MD was found in the vicinity. The analytical results are presented in Appendix C.

The groundwater in the vicinity of Well 6-6 is anticipated to flow to the southeast, toward Mangrove Bay.

The maximum detected concentration of each analyte is compared to PSVs (if available) in Table 5-2. Explosives were not detected in any of the groundwater samples collected at MRS 06N. None of the other PCOPCs exceeded PSVs at site MRS 06N.

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Table 5-1: Soil Source Evaluation MRS 06 NORTH

Analyte	Units	Maximum Detected Concentration		Soil Type	Back-ground Value mg/kg	Potential MC?	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Explosives - SW8330B										
1,3,5-Trinitrobenzene	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	0.38	No	No	Not detected at MRS
1,3-Dinitrobenzene	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	0.61	No	No	Not detected at MRS
2,4,6-Trinitrotoluene	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	6.4	No	No	Not detected at MRS
2,4-Dinitrotoluene	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	1.3	No	No	Not detected at MRS
2,6-Dinitrotoluene	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	0.033	Yes	Yes	Not detected at MRS
2-Amino-4,6-dinitrotoluene	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	10	No	No	Not detected at MRS
2-Nitrotoluene	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	2.9	No	No	Not detected at MRS
3-Nitrotoluene	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	0.61	No	No	Not detected at MRS
4-Amino-2,6-dinitrotoluene	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	3.6	No	No	Not detected at MRS
4-Nitrotoluene	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	22	No	No	Not detected at MRS
Hexahydro-1,3,5-trinitro-1,3,5-triazine	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	5.6	No	No	Not detected at MRS
Nitrobenzene	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	1.3	No	No	Not detected at MRS
Nitroglycerin	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	0.61	No	No	Not detected at MRS
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	27	No	No	Not detected at MRS
PETN	mg/kg	< 1.0	UJ	DeE2	N/A	Yes	100	No	No	Not detected at MRS
Methyl-2,4,6-trinitrophenylnitramine (tetryl)	mg/kg	< 0.200	UJ	DeE2	N/A	Yes	0.99	No	No	Not detected at MRS

Analyte	Units	Maximum Detected Concentration		Soil Type	Back-ground Value mg/kg	Potential MC?	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Metals - SW6020A/SW3050B										
Aluminum	mg/kg	27,000		DeE2	**55,000**	Yes	55,000	No	No	Does not exceed PSV
Barium	mg/kg	1,100		DeE2	**710**	Yes	710	Yes	Yes	--
Chromium	mg/kg	13		DeE2	23	Yes	26	No	No	Does not exceed PSV
Copper	mg/kg	310	J-	DeE2	**360**	Yes	360	No	No	Does not exceed PSV
Lead	mg/kg	19		DeE2	**98**	Yes	98	No	No	Does not exceed PSV
Zinc	mg/kg	200	J-	DeE2	**350**	Yes	350	No	No	Does not exceed PSV
Antimony	mg/kg	0.160	J	DeE2	**1.2**	Yes	1.2	No	No	Does not exceed PSV
Mercury	mg/kg	0.033	J	DeE2	0.051	Yes	0.1	No	No	Does not exceed PSV

U = undetected at the stated reporting limit.

J = (Estimated, Bias Indeterminate): The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated due to non-conformances discovered during data validation.

J- = (Estimated, Low Bias): The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated, displaying low bias, due to non-conformances discovered during data validation.

N/A = Not Applicable.

Table 5-2: Groundwater Source Evaluation MRS 06 NORTH (PR-CUL-GW-MRS-06-6)

Analyte	Units	Maximum Detected Concentration		Potential MC?	Back-ground Value µg/L	PSV [1]	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Explosives - SW8330B									
1,3,5-Trinitrobenzene	µg/L	0.30	U	Yes	0	46	No	No	Not detected at MRS
1,3-Dinitrobenzene	µg/L	0.30	U	Yes	0	0.15	No	No	Not detected at MRS
2,4,6-Trinitrotoluene (TNT)	µg/L	0.30	U	Yes	0	0.76	No	No	Not detected at MRS
2,4-Dinitrotoluene	µg/L	0.30	U	Yes	0	0.20	No	No	Not detected at MRS
2,6-Dinitrotoluene	µg/L	0.30	U	Yes	0	0.042	No	No	Not detected at MRS
2-Amino-4,6-Dinitrotoluene	µg/L	0.30	U	Yes	0	3.0	No	No	Not detected at MRS
2-Nitrotoluene	µg/L	0.30	U	Yes	0	0.27	No	No	Not detected at MRS
3-Nitrotoluene	µg/L	0.30	U	Yes	0	0.13	No	No	Not detected at MRS
4-Amino-2,6-Dinitrotoluene	µg/L	0.30	U	Yes	0	3.0	No	No	Not detected at MRS
4-Nitrotoluene	µg/L	0.30	U	Yes	0	3.7	No	No	Not detected at MRS
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	µg/L	0.30	U	Yes	0	0.61	No	No	Not detected at MRS
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	µg/L	0.30	U	Yes	0	6.1	No	No	Not detected at MRS
Nitrobenzene	µg/L	0.30	U	Yes	0	0.12	No	No	Not detected at MRS
Nitroglycerin	µg/L	0.30	U	Yes	0	0.15	No	No	Not detected at MRS
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	µg/L	0.30	U	Yes	0	78	No	No	Not detected at MRS
Pentaerythritol Tetranitrate (PETN)	µg/L	1.5	U	Yes	0	3.0	No	No	Not detected at MRS
Ammonium Picrate - SW8321A									
Ammonium picrate	µg/L	0.12	U	Yes	0	NA	No	No	Not detected at MRS
Total Metals - SW/7470A									
Aluminum	µg/L	24	B	Yes	NA	1,600	No	No	Detected in equipment blank [2]

Analyte	Units	Maximum Detected Concentration		Potential MC?	Back-ground Value µg/L	PSV [1]	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Antimony	µg/L	0.50	U	Yes	NA	0.60	No	No	Not detected at MRS
Barium	µg/L	63		Yes	NA	290	No	No	Does not exceed PSV
Chromium(total)	µg/L	0.14	B	Yes	NA	NA	No	No	Detected in equipment blank [2]
Chromium(III) [3]	µg/L	N/A [2]		Yes	NA	1,600	No	No	Detected in equipment blank [2]
Chromium(VI) [3]	µg/L	N/A [2]		Yes	NA	0.031	No	No	Detected in equipment blank [2]
Copper	µg/L	8.6		Yes	NA	62	No	No	Does not exceed PSV
Lead	µg/L	0.22	J	Yes	NA	15	No	No	Does not exceed PSV
Mercury	µg/L	0.10	B	Yes	NA	0.43	No	No	Detected in equipment blank [2]
Zinc	µg/L	32		Yes	NA	470	No	No	Does not exceed PSV
					NA				
Perchlorate - SW6850					NA				
Perchlorate	µg/L	0.40	U	Yes	NA	1.1	No	No	Not detected at MRS

(NO CODE) - Confirmed identification.

U - Analyte was analyzed for but not detected above the limit of detection (LOD).

J - Analyte detected, estimated concentration.

NA - Screening criterion not available

N/A - Not Applicable

(1) USEPA RSLs for Tapwater (Target Risk = 10-6; Hazard Quotient = 0.1), November 2013. (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/docs/master_sl_table_01run_NOV2013.pdf)

(2) B qualified data were treated as nondetected chemicals because the chemical was detected in the associated blank and the estimated chemical concentration in the sample was not five times greater than the concentration in the associated blank (RAGS A, USEPA, 1989).

Analyte	Units	Maximum Detected Concentration	Potential MC?	Back-ground Value µg/L	PSV [1]	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation

(3) Chromium can exist in the environment as chromium (III) and chromium (VI). The analytical results presented in this report are for chromium (total) and do not distinguish between the different valence states. It is assumed that total chromium is composed of chromium (VI) and chromium (III) in a 1 to 6 ratio. The estimated chromium (VI) concentration is calculated by dividing the maximum chromium (total) concentration measured in soil samples by 7. For the site concentration, the maximum chromium (total) concentration is 1.5 µg/L. Therefore, the estimated chromium(VI) concentration is 0.21 µg/L and the chromium(III) concentration is estimated as 1.3 µg/L.

5.4.1.2 MRS 06 South

Surface Soil

In support of the RI, two surface soil samples were collected from MRS 06S. One surface soil sample (PR-1014-S-083) was collected from DeE2 soils and one surface soil sample (PR-1014-S-082) was collected from Rs soils. Both samples were analyzed for explosives and eight MC metals. The analytical results are presented in Appendix C. Additionally, two soil samples from this area were collected and analyzed for the 2007 SI and those results were considered in this assessment. These samples were collected from Rs soils.

The maximum detected concentration of each analyte detected in surface soil is compared to respective PSVs in Table 5-3. Explosives were not detected in any of the soil samples collected at MRS 06S. Therefore, explosives were not retained for further consideration in this risk assessment. The maximum detected concentration of all eight metals did not exceed their respective PSVs at MRS 06S. With the exception of antimony, chromium, and lead, the maximum detected concentrations of metals at MRS 06S were in samples collected in DeE2 soils. However, the maximum detected concentrations of metals in samples collected in Rs soils, including antimony, chromium, and lead, at this MRS also did not exceed their respective PSVs. Therefore, metals were not retained for further consideration in this human health or ecological risk assessment.

Surface Water

No surface water sampling was conducted in MRS 06 South due to no MEC findings and the low density of MD indicating no evidence of concentrated munitions use.

Groundwater

To evaluate the potential risk attributable to MC associated with exposure to groundwater in the southern portion of MRS 06, one groundwater sample (PR-CUL-GW-MRS-06-9, and duplicate PR-CUL-GW-MRS-06-10) were collected from an existing well identified as Well 6-9 at MRS 06S and analyzed for explosives, ammonium picrate, eight MC metals, perchlorate, chloride, and nitrate/nitrite as N. The analytical results are presented in Appendix C.

The groundwater flow in the vicinity of well 6-09 is anticipated to flow perpendicular to topographic contours to the northwest towards Mosquito Bay. Well 6-09 is located less than 200 ft from the shoreline. High salinity and chloride concentrations in groundwater at this location make the water unsuitable for consumption without desalination. The well is not considered representative of all groundwater at Culebra.

The maximum detected concentration of each analyte is compared to PSVs (if available) in Table 5-4. Explosives were not detected in any of the groundwater samples at MRS 06. The estimated maximum concentration of chromium (VI) (0.21 µg/L), which is equal to the maximum detected total chromium concentration divided by seven, exceeded its PSV (0.031 µg/L). Therefore, chromium will be further evaluated in the risk assessment.

Table 5-3: Soil Source Evaluation MRS 06 South

Analyte	Units	Maximum Detected Concentration		Soil Type	Potential MC?	Background Value mg/kg	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Explosives - SW8330B										
1,3,5-Trinitrobenzene	mg/kg	< 0.200	UJ	Rs	Yes	0	0.38	No	No	Not detected at MRS
1,3-Dinitrobenzene	mg/kg	< 0.200	UJ	Rs	Yes	0	0.61	No	No	Not detected at MRS
2,4,6-Trinitrotoluene	mg/kg	< 0.200	UJ	Rs	Yes	0	6.4	No	No	Not detected at MRS
2,4-Dinitrotoluene	mg/kg	< 0.200	UJ	Rs	Yes	0	1.3	No	No	Not detected at MRS
2,6-Dinitrotoluene	mg/kg	< 0.200	UJ	Rs	Yes	0	0.033	No	No	Not detected at MRS
2-Amino-4,6-dinitrotoluene	mg/kg	< 0.200	UJ	Rs	Yes	0	10	No	No	Not detected at MRS
2-Nitrotoluene	mg/kg	< 0.200	UJ	Rs	Yes	0	2.9	No	No	Not detected at MRS
3-Nitrotoluene	mg/kg	< 0.200	UJ	Rs	Yes	0	0.61	No	No	Not detected at MRS
4-Amino-2,6-Dinitrotoluene	mg/kg	< 0.200	UJ	Rs	Yes	0	3.6	No	No	Not detected at MRS
4-Nitrotoluene	mg/kg	< 0.200	UJ	Rs	Yes	0	22	No	No	Not detected at MRS
Hexahydro-1,3,5-trinitro-1,3,5-triazine	mg/kg	< 0.200	UJ	Rs	Yes	0	5.6	No	No	Not detected at MRS
Nitrobenzene	mg/kg	< 0.200	UJ	Rs	Yes	0	1.3	No	No	Not detected at MRS
Nitroglycerin	mg/kg	< 0.200	UJ	Rs	Yes	0	0.61	No	No	Not detected at MRS
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	mg/kg	< 0.200	UJ	Rs	Yes	0	27	No	No	Not detected at MRS
PETN	mg/kg	< 1.000	UJ	Rs	Yes	0	100	No	No	Not detected at MRS

Analyte	Units	Maximum Detected Concentration		Soil Type	Potential MC?	Background Value mg/kg	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Methyl-2,4,6-trinitro-phenylnitramine (tetryl)	mg/kg	< 0.200	UJ	Rs	Yes	0	0.99	No	No	Not detected at MRS
Metals - SW6020A/SW3050B, 7471B										
Aluminum	mg/kg	32,000		DeE2	Yes	**55,000**	55,000	No	No	Does not exceed PSV
Barium	mg/kg	350 J		DeE2	Yes	**710**	710	No	No	Does not exceed PSV
Chromium	mg/kg	19 (1)		Rs	Yes	34	34	No	No	Does not exceed PSV
Copper	mg/kg	230 J-		DeE2	Yes	**360**	360	No	No	Does not exceed PSV
Lead	mg/kg	15 (1)		Rs	Yes	**220**	220	No	No	Does not exceed PSV
Zinc	mg/kg	100 J-		DeE2	Yes	**350**	350	No	No	Does not exceed PSV
Antimony	mg/kg	0.160 J		Rs	Yes	1.3	1.3	No	No	Does not exceed PSV
Mercury	mg/kg	0.048 J		DeE2	Yes	0.051	0.1	No	No	Does not exceed PSV

U = Undetected at the stated reporting limit.

J- = (Estimated, Low Bias): The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated, displaying low bias, due to non-conformances discovered during data validation.

J= (Estimated, Bias Indeterminate): The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated due to non-conformances discovered during data validation.

(1) - Maximum detected concentration is from the 2007 SI Report (Parsons, 2007)

Table 5-4: Groundwater Source Evaluation MRS 06 South (PR-CUL-GW-MRS-06-9 and duplicate PR-CUL-GW-MRS-06-10)

Analyte	Units	Maximum Detected Concentration		Potential MC?	Back-ground Value µg/L	PSV [1]	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
	Explosives - SW8330B								
1,3,5-Trinitrobenzene	µg/L	0.30	U	Yes	N/A	46	No	No	Not detected at MRS
1,3-Dinitrobenzene	µg/L	0.30	U	Yes	N/A	0.15	No	No	Not detected at MRS
2,4,6-Trinitrotoluene (TNT)	µg/L	0.30	U	Yes	N/A	0.76	No	No	Not detected at MRS
2,4-Dinitrotoluene	µg/L	0.30	U	Yes	N/A	0.20	No	No	Not detected at MRS
2,6-Dinitrotoluene	µg/L	0.30	U	Yes	N/A	0.042	No	No	Not detected at MRS
2-Amino-4,6-dinitrotoluene	µg/L	0.30	U	Yes	N/A	3.0	No	No	Not detected at MRS
2-Nitrotoluene	µg/L	0.30	U	Yes	N/A	0.27	No	No	Not detected at MRS
3-Nitrotoluene	µg/L	0.30	U	Yes	N/A	0.13	No	No	Not detected at MRS
4-Amino-2,6-Dinitrotoluene	µg/L	0.30	U	Yes	N/A	3.0	No	No	Not detected at MRS
4-Nitrotoluene	µg/L	0.30	U	Yes	N/A	3.7	No	No	Not detected at MRS
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	µg/L	0.30	U	Yes	N/A	0.61	No	No	Not detected at MRS
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	µg/L	0.30	U	Yes	N/A	6.1	No	No	Not detected at MRS
Nitrobenzene	µg/L	0.30	U	Yes	N/A	0.12	No	No	Not detected at MRS
Nitroglycerin	µg/L	0.30	U	Yes	N/A	0.15	No	No	Not detected at MRS
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	µg/L	0.30	U	Yes	N/A	78	No	No	Not detected at MRS
Pentaerythritol Tetranitrate (PETN)	µg/L	1.5	U	Yes	N/A	3.0	No	No	Not detected at MRS
	Ammonium Picrate - SW8321A								
Ammonium picrate	µg/L	0.12	U	Yes	N/A	NA	No	No	Not detected at MRS

Analyte	Units	Maximum Detected Concentration		Potential MC?	Back-ground Value µg/L	PSV [1]	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Total Metals - SW6020A, 7470A									
Aluminum	µg/L	18	B	Yes	NA	1,600	No	No	Detected in equipment blank [2]
Antimony	µg/L	0.19	J	Yes	NA	0.60	No	No	Does not exceed PSV
Barium	µg/L	78		Yes	NA	290	No	No	Does not exceed PSV
Chromium(total)	µg/L	1.5		Yes	NA	NA	N/A	N/A	N/A
Chromium(III) [3]	µg/L	1.3		Yes	NA	1,600	No	No	Does not exceed PSV
Chromium(VI) [3]	µg/L	0.21		Yes	NA	0.031	**Yes**	--	--
Copper	µg/L	19	J	Yes	NA	62	No	No	Does not exceed PSV
Lead	µg/L	0.26	J	Yes	NA	15	No	No	Does not exceed PSV
Mercury	µg/L	0.071	B	Yes	NA	0.43	No	No	Detected in equipment blank [2]
Zinc	µg/L	330	J	Yes	NA	470	No	No	Does not exceed PSV
Perchlorate - SW6850									
Perchlorate	µg/L	1.1	J	Yes	NA	1.1	No	No	Does not exceed PSV

(NO CODE) - Confirmed identification.
U - Analyte was analyzed for but not detected above the limit of detection (LOD).
J - Analyte detected, estimated concentration.
NA - Screening criterion not available
N/A - Not Applicable
(1) USEPA RSLs for Tapwater (Target Risk = 10-6; Hazard Quotient = 0.1), November 2013. (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/docs/master_sl_table_01run_NOV2013.pdf)
(2) B qualified data were treated as nondetected chemicals because the chemical was detected in the associated blank and the estimated chemical concentration in the sample was not five times greater than the concentration in the associated blank (RAGS A, USEPA, 1989).
(3) Chromium can exist in the environment as chromium (III) and chromium (VI). The analytical results presented in this report are for chromium (total) and do not distinguish between the different valence states. It is assumed that total chromium is composed of chromium (VI) and chromium (III) in a 1 to 6 ratio. The estimated chromium (VI) concentration is calculated by dividing the maximum chromium (total) concentration measured in soil samples by 7. For the site concentration, the maximum chromium (total) concentration is 1.5 µg/L. Therefore, the estimated chromium(VI) concentration is 0.21 µg/L and the chromium(III) concentration is estimated as 1.3 µg/L.

5.4.1.3 MRS 08

Surface Soil

In support of the RI, a total of 12 surface soil samples were collected from MRS 08. Two surface soil samples (PR-1013-S-070 and PR-1013-S-073) were collected within DeE2 soils and 10 surface soil samples (PR-1013-S-071, PR-1013-S-072, and PR-1013-S-074 through PR-1013-S-081) were collected within DrF soils. All samples were analyzed for explosives and eight metals. The analytical results are presented in Appendix C. Additionally, two soil samples from this area were collected and analyzed in the 2007 SI and those results were considered in this assessment.

The maximum detected concentration of each analyte detected in surface soil is compared to PSVs in Table 5-5. Explosives were not detected in any of the soil samples collected at MRS 08. Therefore, explosives were not retained for further consideration in this risk assessment. The maximum detected concentration of all eight metals did not exceed their respective PSVs at MRS 08. The maximum detected concentrations of metals at MRS 08 were in samples collected in DrF soils. However, the maximum detected concentrations of metals in samples collected in DeE2 soils at this MRS also did not exceed their respective PSVs. Therefore, metals were not retained for further consideration in this human health or ecological risk assessment.

Surface Water

No surface water samples were collected from this MRS during the RI because no perennial water source was present. As a result, the surface water exposure pathway is incomplete and is not considered further in this risk assessment.

Sediment

One sediment sample was collected and analyzed during the 2007 SI. The sediment is composed of material derived from erosion of the DrF soil type. Six metals were detected in the 2007 SI sediment sample: barium (140 mg/kg); chromium (2.1 mg/kg); copper (19 mg/kg); lead (5.9 mg/kg); zinc (61 mg/kg); and mercury (0.011 mg/kg). These sediment samples were retained for evaluation in the SI. As such, none of the concentrations of metals detected in the 2007 SI samples exceeded their PSVs. The SI determined there were no unacceptable risks present to human health. No unacceptable risks were present to ecological receptors for metals, with the exception of barium. At the time, there was no ecological screening value for barium, and potential risks from barium exposure for ecological receptors was deemed inconclusive due to the lack of a screening level for comparison. The 2007 sampling event was conducted after considerable rain events; however, during the 2011 RI sampling event the surface water was no longer present. No sediment or surface water samples were collected from this MRS during the RI because no perennial water source was present. Therefore, the 2007 sediment data are considered in this RI as soil data. A comparison of the 2007 detected level (140 mg/kg) to the USEPA Eco SSL for soil (330 mg/kg) indicates no exceedance. As a result, the sediment/surface water exposure pathway is incomplete and is not considered further in this risk assessment. Based on the results of SI and RI sampling at MRS 08 metals were not retained for further consideration in this risk assessment.

Groundwater

Surface soil and sediment samples did not produce exceedances in metal or explosive PSVs. No wells are present on MRS 08, and there is no evidence groundwater has been used as a source of potable water. There are currently no permanent residences on the island. According to the USGS 2014, *Hydrogeology of Puerto Rico and the Outlying Islands of Vieques, Culebra and Mona,* when evaluating the aquifers in the outlying islands of Vieques, Culebra, and Mona, only Vieques was reported to be underlain by aquifers of any local importance. No aquifers were identified on Cayo Norte (MRS 08).

Figure 5-1 identifies the locations of Culebra aquifers to include Cayo Norte in which none are anticipated to exist.

The cayo is zoned for very low density residential, of one home per 25 acres. The land owner indicated the source of fresh water intended for any future residential properties is from rain water collected from rooftops and/or the desalination of salt water, using solar energy to power a package desalinator.

Given the impermeable nature of the volcanic rock with storage located within fracturing, the acreage of the island that would significantly be impacted by saltwater intrusion, the lack of known aquifers, minimal MD discovered, and no MC source that poses a human health risk, there is no human health risk due to exposure to groundwater. Therefore the groundwater pathway is considered incomplete.

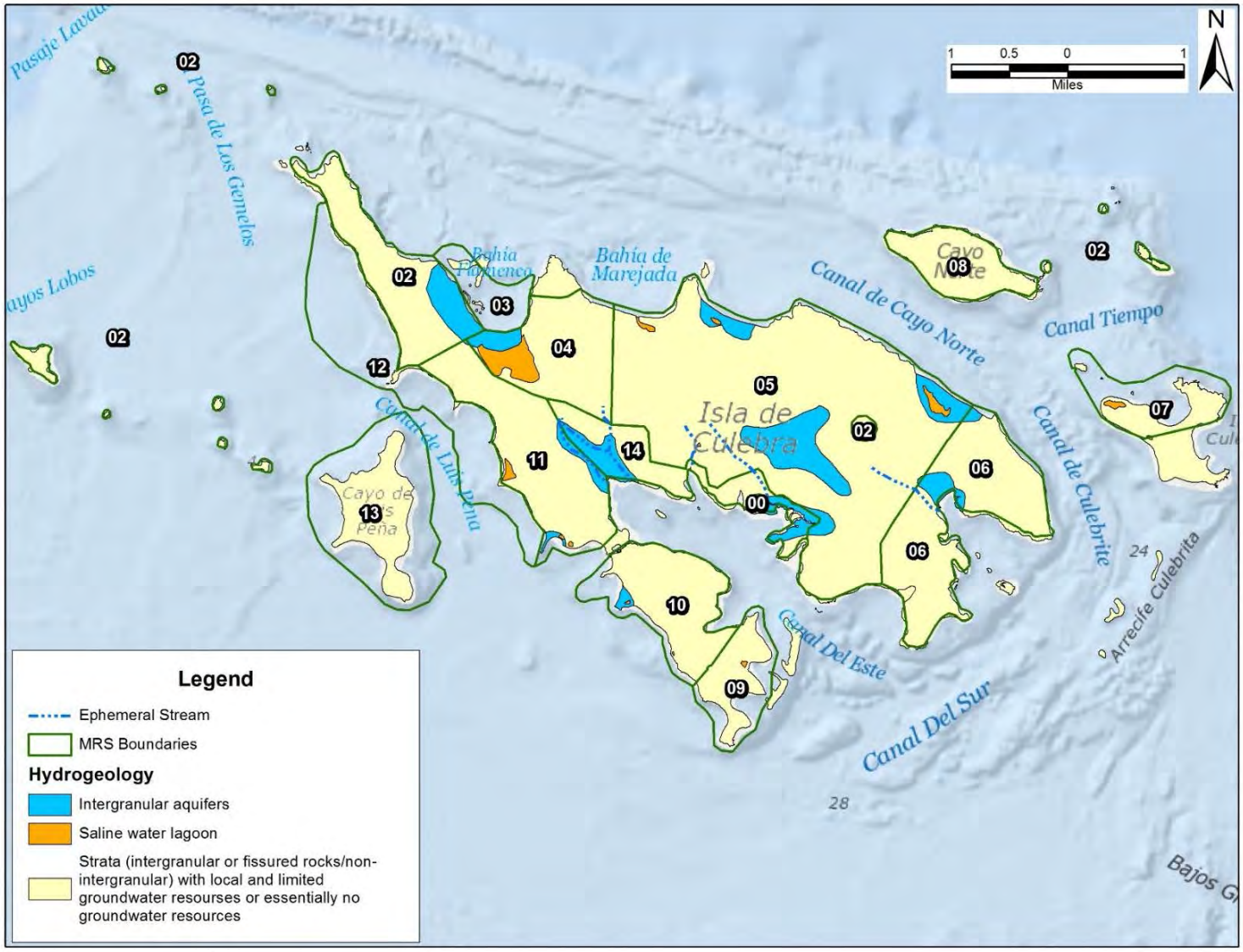

Figure 5-1: USGS 2014, Hydrogeology of Puerto Rico and the Outlying Islands (Plate 1 with MRS Boundaries added)

Table 5-5: Soil Source Evaluation MRS 08

Analyte	Units	Maximum Detected Concentration		Soil Type	Back-ground Value mg/kg	Potential MC?	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Explosives - SW8330A										
1,3,5-Trinitrobenzene	mg/kg	< 0.200	U	DrF	N/A	Yes	0.38	No	No	Not detected at MRS
1,3-Dinitrobenzene	mg/kg	< 0.200	U	DrF	N/A	Yes	0.61	No	No	Not detected at MRS
2,4,6-Trinitrotoluene	mg/kg	< 0.200	U	DrF	N/A	Yes	6.4	No	No	Not detected at MRS
2,4-Dinitrotoluene	mg/kg	< 0.200	U	DrF	N/A	Yes	1.3	No	No	Not detected at MRS
2,6-Dinitrotoluene	mg/kg	< 0.200	U	DrF	N/A	Yes	0.033	No	No	Not detected at MRS
2-Amino-4,6-dinitrotoluene	mg/kg	< 0.200	U	DrF	N/A	Yes	10	No	No	Not detected at MRS
2-Nitrotoluene	mg/kg	< 0.200	U	DrF	N/A	Yes	2.9	No	No	Not detected at MRS
3-Nitrotoluene	mg/kg	< 0.200	U	DrF	N/A	Yes	0.61	No	No	Not detected at MRS
4-Amino-2,6-Dinitrotoluene	mg/kg	< 0.200	U	DrF	N/A	Yes	3.6	No	No	Not detected at MRS
4-Nitrotoluene	mg/kg	< 0.200	U	DrF	N/A	Yes	22	No	No	Not detected at MRS
Hexahydro-1,3,5-trinitro-1,3,5-triazine	mg/kg	< 0.200	U	DrF	N/A	Yes	5.6	No	No	Not detected at MRS
Nitrobenzene	mg/kg	< 0.200	U	DrF	N/A	Yes	1.3	No	No	Not detected at MRS
Nitroglycerin	mg/kg	< 0.200	U	DrF	N/A	Yes	0.61	No	No	Not detected at MRS
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	mg/kg	< 0.200	U	DrF	N/A	Yes	27	No	No	Not detected at MRS
PETN	mg/kg	< 1.000	U	DrF	N/A	Yes	100	No	No	Not detected at MRS
Methyl-2,4,6-trinitrophenylnitramine (tetryl)	mg/kg	< 0.200	U	DrF	N/A	Yes	0.99	No	No	Not detected at MRS
Metals - SW6020A/SW3050B, 7471B										
Aluminum	mg/kg	31,000		DrF	**56,000**	Yes	56,000	No	No	Does not exceed PSV
Barium	mg/kg	290		DrF	**430**	Yes	430	No	No	Does not exceed PSV

Analyte	Units	Maximum Detected Concentration	Soil Type	Back-ground Value mg/kg	Potential MC?	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Chromium	mg/kg	3.10 J	DrF	**30**	Yes	30	No	No	Does not exceed PSV
Copper	mg/kg	43	DrF	**140**	Yes	140	No	No	Does not exceed PSV
Lead	mg/kg	13	DrF	**17**	Yes	17	No	No	Does not exceed PSV
Zinc	mg/kg	110	DrF	**220**	Yes	220	No	No	Does not exceed PSV
Antimony	mg/kg	0.190 J	DrF	**0.30**	Yes	0.30	No	No	Does not exceed PSV
Mercury	mg/kg	0.066	DrF	0.032	Yes	0.1	No	No	Does not exceed PSV

U = undetected at the stated reporting limit.

J = (Estimated, Bias Indeterminate): The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated due to non-conformances discovered during data validation.

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5.4.1.4 MRS 09

Surface Soil

In support of the RI, six surface soil samples (PR-1012-S-029 through PR-1012-S-034) were collected from Rs soils at MRS 09 and were analyzed for explosives and eight metals. Four post-detonation samples (PR-0013-CPST through PR-0016-CPST) were also collected at a consolidation location where marine flares found at MRS 09 and items from other MRSs were detonated; these four post-detonation samples were analyzed for explosives only. The analytical results are presented in Appendix C. Additionally, two soil samples from this area were collected and analyzed in the 2007 SI and those results were considered in this assessment.

The maximum detected concentration of each analyte is compared to PSVs in Table 5-6. Explosives were not detected in any of the soil samples collected at MRS 09. Therefore, explosives were not retained for further consideration in this risk assessment. The maximum detected concentration of all eight metals did not exceed their respective PSVs at MRS 09. Therefore, metals in surface soil were not retained for further consideration in this risk assessment.

The results for the explosive tetryl in the demolition samples (PR-0009-CPRE, PR-0010-CPRE, PR-0011-CPRE, PR-0012-CPRE, PR-0013-CPST, PR-0014-CPST, PR-0015-CPST, and PR-0016-CPST) collected in 2012 from the second demolition at the one demolition site located in MRS 09 were rejected. The samples were re-collected in December 2016 and no explosives were detected.

Surface Water

In support of the RI, three surface water samples (PR-1012-SW-035 through PR-1012-SW-037) were collected at MRS 09. All samples were analyzed for explosives and eight MC metals. The analytical results are presented in Appendix C. No surface water samples were collected during the 2007 SI; only surface water sampling results from the RI were used for this assessment.

The maximum detected concentration of each analyte is compared to PSVs in Table 5-7. Explosives were not detected in any of the surface water samples collected at MRS 09. Therefore, explosives were not retained for further consideration in this risk assessment. The maximum detected concentration of all eight metals did not exceed their respective surface water PSVs at MRS 09. Therefore, metals in surface water were not retained for further consideration in this risk assessment.

Sediment

In support of the RI, three sediment samples (PR-1012-SD-035, PR-022517-SD-036-RE, and PR-1012-SD-037) were collected at MRS 09. The sediment at this location is composed of Rs soils eroded from the upgradient areas. The samples were analyzed for explosives and eight metals. The metals container for sediment sample 36 was broken in shipment in the 2011 sampling event, and therefore metals analysis was also included in the re-sampling event, and results for PR-022517-SD-036-RE are reported in this RI Report. Additionally, this sediment sample was moved across the lagoon to give the sediment samples more separation and provide better representation of conditions in the lagoon. The analytical results are presented in

Appendix C. No sediment samples were collected during the 2007 SI; only sediment sampling results from the RI were used for this assessment.

The maximum detected concentration of each analyte is compared to PSVs in Table 5-8. Explosives were not detected in any of the sediment samples collected at MRS 09. Therefore, explosives were not retained for further consideration in this risk assessment. The maximum detected concentration of six metals (barium, chromium, lead, zinc, antimony, and mercury) did not exceed their respective PSVs at MRS 09. The maximum detected concentrations of aluminum (68,000 mg/kg) and copper (390 mg/kg) were greater than their respective PSVs (57,000 and 310 mg/kg) (see Appendix A: Figure A-28). Since sediment at MRS 09 was sampled in a small collection lagoon that does not have an outfall or discharge in any way to other surface water bodies, no additional sediment samples were collected to delineate aluminum and copper in sediment. If the lagoon had an outfall, a pathway downstream potentially could have been present for migration toward Mangrove Bay. However, since no outfall was present, no further sampling was conducted. Based on an evaluation of topographic maps in the area and the proximity of the lagoon to Mangrove Bay, groundwater flow is likely to the southwest, eventually ending in the direction of Mangrove Bay. It is possible that aluminum and copper could leach to groundwater, but given the proximity to highly saline water, it is quite unlikely the water would be used as a groundwater source. Additionally, the relatively minor exceedances are attributed to both naturally occurring elevated values and accumulation of eroded metals sorbing to particles in the lagoon. However, aluminum and copper are considered COPCs in sediment and were retained for further consideration in this risk assessment even though aluminum is not considered a CERCLA hazardous substance.

Groundwater

To evaluate potential risk attributable to MC associated with exposure to groundwater in MRS 09, one groundwater sample (PR-CUL-GW-MRS-09-3 was collected from a newly installed monitoring well at MRS 09 identified as well 9-3 and analyzed for explosives, ammonium picrate, eight MC metals, perchlorate, chloride, and nitrate/nitrite as N. The analytical results are presented in Appendix C.

The location of well 9-3 rests on a topographic saddle and as its location is in the western half of the peninsula, groundwater is anticipated to flow to the southwest and into the Atlantic Ocean. Well 9-3 is located less than 200 ft from the shoreline. High salinity and chloride concentrations in groundwater at this location make the water unsuitable for consumption without desalination. The well is not considered representative of all groundwater at Culebra.

The maximum detected concentration of each analyte is compared to PSVs (if available) in Table 5-9. Explosives were not detected in any of the groundwater samples collected at MRS 09. The maximum detected concentration of copper (140 µg/L) was greater than its PSV (62 µg/L) (see Appendix A: Maps, Figure A-28). The estimated maximum concentration of chromium (VI) (0.036 µg/L), which is equal to the maximum detected total chromium concentration divided by seven, exceeded its PSV (0.031 µg/L). Copper and chromium will be retained for further consideration in the risk assessment.

Table 5-6: Soil Source Evaluation MRS 09[(1)]

Analyte	Units	Maximum Detected Concentration		Soil Type	Back-ground Value mg/kg	Potential MC?	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Explosives - SW8330B										
1,3,5-Trinitrobenzene	mg/kg	< 0.200	U	Rs	0	Yes	0.38	No	No	Not detected at MRS
1,3-Dinitrobenzene	mg/kg	< 0.200	U	Rs	0	Yes	0.61	No	No	Not detected at MRS
2,4,6-Trinitrotoluene	mg/kg	< 0.200	U	Rs	0	Yes	6.4	No	No	Not detected at MRS
2,4-Dinitrotoluene	mg/kg	< 0.200	U	Rs	0	Yes	1.3	No	No	Not detected at MRS
2,6-Dinitrotoluene	mg/kg	< 0.200	U	Rs	0	Yes	0.033	No	No	Not detected at MRS
2-Amino-4,6-dinitrotoluene	mg/kg	< 0.200	U	Rs	0	Yes	10	No	No	Not detected at MRS
2-Nitrotoluene	mg/kg	< 0.200	U	Rs	0	Yes	2.9	No	No	Not detected at MRS
3-Nitrotoluene	mg/kg	< 0.200	U	Rs	0	Yes	0.61	No	No	Not detected at MRS
4-Amino-2,6-Dinitrotoluene	mg/kg	< 0.200	U	Rs	0	Yes	3.6	No	No	Not detected at MRS
4-Nitrotoluene	mg/kg	< 0.200	U	Rs	0	Yes	22	No	No	Not detected at MRS
Hexahydro-1,3,5-trinitro-1,3,5-triazine	mg/kg	< 0.200	U	Rs	0	Yes	5.6	No	No	Not detected at MRS
Nitrobenzene	mg/kg	< 0.200	U	Rs	0	Yes	1.3	No	No	Not detected at MRS
Nitroglycerin	mg/kg	< 0.200	U	Rs	0	Yes	0.61	No	No	Not detected at MRS
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	mg/kg	< 0.200	U	Rs	0	Yes	27	No	No	Not detected at MRS
PETN	mg/kg	< 1.000	U	Rs	0	Yes	100	No	No	Not detected at MRS
Methyl-2,4,6-trinitrophenylnitramine (tetryl)	mg/kg	< 0.200	U	Rs	0	Yes	0.99	No	No	Not detected at MRS
Metals - SW6020A/SW3050B, SW7471B										
Aluminum	mg/kg	43,000		Rs	**57,000**	Yes	57,000	No	No	Does not exceed PSV
Barium	mg/kg	360		Rs	**960**	Yes	960	No	No	Does not exceed PSV

Analyte	Units	Maximum Detected Concentration		Soil Type	Back-ground Value mg/kg	Potential MC?	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Chromium	mg/kg	19 (2)		Ts(3)	24	Yes	26	No	No	Does not exceed PSV
Copper	mg/kg	190	J	Rs	**310**	Yes	310	No	No	Does not exceed PSV
Lead	mg/kg	8.8 (2)		Ts(3)	**11**	Yes	11	No	No	Does not exceed PSV
Zinc	mg/kg	82	J	Rs	**500**	Yes	500	No	No	Does not exceed PSV
Antimony	mg/kg	0.096	J	Rs	1.3	Yes	1.3	No	No	Does not exceed PSV
Mercury	mg/kg	0.094		Rs	0.60	Yes	0.60	No	No	Does not exceed PSV

U = undetected at the stated reporting limit.

J = (Estimated, Bias Indeterminate): The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated due to non-conformances discovered during data validation.

(1) Table 5-6 maximum detected concentrations include values fromthe RI and SI.
(2) Maximum detected concentrations from the 2007 SI Report (Parsons, 2007)
(3) Soil type at location of 2007 SI sample.

Table 5-7: Surface Water Source Evaluation MRS 09

Analyte	Units	Maximum Detected Concentration		Potential MC?	Back-ground Value	PSV	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
1,3,5-Trinitrobenzene	µg/L	< 0.300		Yes	N/A	8.7	No	No	Not detected at MRS
1,3-Dinitrobenzene	µg/L	< 0.300		Yes	N/A	0.15	No	No	Not detected at MRS
2,4,6-Trinitrobenzene	µg/L	< 0.300		Yes	N/A	2.2	No	No	Not detected at MRS
2,4-Dinitrotoluene	µg/L	< 0.300		Yes	N/A	0.20	No	No	Not detected at MRS
2,6-Dinitrotoluene	µg/L	< 0.300		Yes	N/A	1.5	No	No	Not detected at MRS
2-Amino-4,6-dinitrotoluene	µg/L	< 0.300		Yes	N/A	3.0	No	No	Not detected at MRS
2-Nitrotoluene	µg/L	< 0.300		Yes	N/A	0.27	No	No	Not detected at MRS
3-Nitrotoluene	µg/L	< 0.300		Yes	N/A	0.13	No	No	Not detected at MRS
4-Amino-2,6-dinitrotoluene	µg/L	< 0.300		Yes	N/A	3.0	No	No	Not detected at MRS
4-Nitrotoluene	µg/L	< 0.300		Yes	N/A	3.7	No	No	Not detected at MRS
Hexahydro-1,3,5-trinitro-1,3,5-triazine	µg/L	< 0.300		Yes	N/A	0.61	No	No	Not detected at MRS
Nitrobenzene	µg/L	< 0.300		Yes	N/A	0.12	No	No	Not detected at MRS
Nitrogylcerin	µg/L	< 0.300		Yes	N/A	0.15	No	No	Not detected at MRS
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	µg/L	< 0.300		Yes	N/A	78	No	No	Not detected at MRS
PETN	µg/L	< 1.500		Yes	N/A	16	No	No	Not detected at MRS
Tetryl	µg/L	< 0.300		Yes	N/A	6.3	No	No	Not detected at MRS
	Metals - SW6020A/SW3020B, SW7470A								
Aluminum	µg/L	910	J+	Yes	**1,700**	1,700	No	No	Does not exceed PSV
Barium	µg/L	17		Yes	**360**	360	No	No	Does not exceed PSV

Chromium	µg/L	< 0.38	U	Yes	3.1	120	No	No	Does not exceed PSV
Copper	µg/L	8.8		Yes	**30**	30	No	No	Does not exceed PSV
Lead	µg/L	0.20	J	Yes	0.41	1.3	No	No	Does not exceed PSV
Zinc	µg/L	5.0	J	Yes	23	59	No	No	Does not exceed PSV
Antimony	µg/L	< 2.0	U	Yes	**3.5**	3.5	No	No	Does not exceed PSV
Mercury	µg/L	0.024	U	Yes	ND	0.012	No	No	Not detected at MRS

U = undetected at the stated reporting limit.

J = (Estimated, Bias Indeterminate): The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated due to non-conformances discovered during data validation.

J+ = Estimated, High Bias: The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated, displaying high bias, due to non-conformances discovered during data validation.

N/A - Not Applicable

ND = Not Detected

Table 5-8: Sediment Source Evaluation MRS 09

Analyte	Units	Maximum Detected Concentration		Soil Type	Back-ground Value mg/kg	Potential MC?	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Explosives - SW8330B										
1,3,5-Trinitrobenzene	mg/kg	< 0.200	U	Rs	N/A	Yes	0.38	No	No	Not detected at MRS
1,3-Dinitrobenzene	mg/kg	< 0.200	U	Rs	N/A	Yes	0.61	No	No	Not detected at MRS
2,4,6-Trinitrotoluene	mg/kg	< 0.200	U	Rs	N/A	Yes	6.4	No	No	Not detected at MRS
2,4-Dinitrotoluene	mg/kg	< 0.200	U	Rs	N/A	Yes	1.3	No	No	Not detected at MRS
2,6-Dinitrotoluene	mg/kg	< 0.200	U	Rs	N/A	Yes	0.033	No	No	Not detected at MRS
2-Amino-4,6-dinitrotoluene	mg/kg	< 0.200	U	Rs	N/A	Yes	10	No	No	Not detected at MRS
2-Nitrotoluene	mg/kg	< 0.200	U	Rs	N/A	Yes	2.9	No	No	Not detected at MRS
3-Nitrotoluene	mg/kg	< 0.200	U	Rs	N/A	Yes	0.61	No	No	Not detected at MRS
4-Amino-2,6-Dinitrotoluene	mg/kg	< 0.200	U	Rs	N/A	Yes	3.6	No	No	Not detected at MRS
4-Nitrotoluene	mg/kg	< 0.200	U	Rs	N/A	Yes	22	No	No	Not detected at MRS
Hexahydro-1,3,5-trinitro-1,3,5-triazine	mg/kg	< 0.200	U	Rs	N/A	Yes	5.6	No	No	Not detected at MRS
Nitrobenzene	mg/kg	< 0.200	U	Rs	N/A	Yes	1.3	No	No	Not detected at MRS
Nitroglycerin	mg/kg	< 0.200	U	Rs	N/A	Yes	0.61	No	No	Not detected at MRS
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	mg/kg	< 0.200	U	Rs	N/A	Yes	27	No	No	Not detected at MRS
PETN	mg/kg	< 1.000	U	Rs	N/A	Yes	100	No	No	Not detected at MRS
Methyl-2,4,6-trinitrophenylnitramine (tetryl)	mg/kg	< 0.200	U	Rs	N/A	Yes	0.99	No	No	Not detected at MRS

Analyte	Units	Maximum Detected Concentration		Soil Type	Back-ground Value mg/kg	Potential MC?	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Metals - SW6020A/SW3050B, 7471B										
Aluminum	mg/kg	68,000		Rs	**57,000**	Yes	57,000	**Yes**	**Yes**	--
Barium	mg/kg	470		Rs	**960**	Yes	960	No	No	Does not exceed PSV
Chromium	mg/kg	20		Rs	34	Yes	52	No	No	Does not exceed PSV
Copper	mg/kg	390	J	Rs	**310**	Yes	310	**Yes**	**Yes**	--
Lead	mg/kg	18		Rs	**220**	Yes	220	No	No	Does not exceed PSV
Zinc	mg/kg	160		Rs	**500**	Yes	500	No	No	Does not exceed PSV
Antimony	mg/kg	0.32	J	Rs	1.3	Yes	3.1	No	No	Does not exceed PSV
Mercury	mg/kg	0.068	J	Rs	**0.60**	Yes	0.60	No	No	Does not exceed PSV

U = undetected at the stated reporting limit.

J = (Estimated, Bias Indeterminate): The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated due to non-conformances discovered during data validation.

N/A - Not Applicable

Table 5-9: Groundwater Source Evaluation MRS 09

Analyte	Units	Maximum Detected Concentration		Potential MC?	Back-ground Value µg/L	PSV mg/kg (1)	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Explosives - SW8330B									
1,3,5-Trinitrobenzene	µg/L	0.30	U	Yes	N/A	46	No	No	Not detected at MRS
1,3-Dinitrobenzene	µg/L	0.30	U	Yes	N/A	0.15	No	No	Not detected at MRS
2,4,6-Trinitrotoluene (TNT)	µg/L	0.30	U	Yes	N/A	0.76	No	No	Not detected at MRS
2,4-Dinitrotoluene	µg/L	0.30	U	Yes	N/A	0.20	No	No	Not detected at MRS
2,6-Dinitrotoluene	µg/L	0.30	U	Yes	N/A	0.042	No	No	Not detected at MRS
2-Amino-4,6-dinitrotoluene	µg/L	0.30	U	Yes	N/A	3.0	No	No	Not detected at MRS
2-Nitrotoluene	µg/L	0.30	U	Yes	N/A	0.27	No	No	Not detected at MRS
3-Nitrotoluene	µg/L	0.30	U	Yes	N/A	0.13	No	No	Not detected at MRS
4-Amino-2,6-Dinitrotoluene	µg/L	0.30	U	Yes	N/A	3.0	No	No	Not detected at MRS
4-Nitrotoluene	µg/L	0.30	U	Yes	N/A	3.7	No	No	Not detected at MRS
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	µg/L	0.30	U	Yes	N/A	0.61	No	No	Not detected at MRS
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	µg/L	0.30	U	Yes	N/A	6.1	No	No	Not detected at MRS
Nitrobenzene	µg/L	0.30	U	Yes	N/A	0.12	No	No	Not detected at MRS
Nitroglycerin	µg/L	0.30	U	Yes	N/A	0.15	No	No	Not detected at MRS
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	µg/L	0.30	U	Yes	N/A	78	No	No	Not detected at MRS
Pentaerythritol Tetranitrate (PETN)	µg/L	1.5	U	Yes	N/A	3.0	No	No	Not detected at MRS
Ammonium Picrate - SW8321A									
Ammonium picrate	µg/L	0.12	U	Yes	N/A	NA	No	No	Not detected at MRS

Analyte	Units	Maximum Detected Concentration		Potential MC?	Back-ground Value µg/L	PSV mg/kg (1)	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Total Metals - SW6020A /7470A									
Aluminum	µg/L	42	B	Yes	NA	1,600	No	No	Detected in equipment blank (2)
Antimony	µg/L	0.26	J	Yes	NA	0.60	No	No	Does not exceed PSV
Barium	µg/L	39		Yes	NA	290	No	No	Does not exceed PSV
Chromium(total)	µg/L	0.25	J	Yes	NA	NA	N/A	N/A	N/A
Chromium(III) (3)	µg/L	0.21		Yes	NA	1,600	No	No	Does not exceed PSV
Chromium(VI) (3)	µg/L	0.036		Yes	NA	0.031	Yes	**Yes**	--
Copper	µg/L	140		Yes	NA	62	Yes	**Yes**	--
Lead	µg/L	1.2		Yes	NA	15	No	No	Does not exceed PSV
Mercury	µg/L	0.15	U	Yes	NA	0.43	No	No	Not detected at MRS
Zinc	µg/L	110		Yes	NA	470	No	No	Does not exceed PSV
Perchlorate - SW6850									
Perchlorate	µg/L	0.40	U	Yes	N/A	1.1	No	No	Not detected at MRS

(NO CODE) - Confirmed identification.
U - Analyte was analyzed for but not detected above the limit of detection (LOD).
J - (Estimated, Bias Indeterminate): The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated due to non-conformances discovered during data validation.
NA - Screening criterion not available
N/A - Not Applicable
(1) USEPA RSLs for Tapwater (Target Risk = 10-6; Hazard Quotient = 0.1), November 2013. (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/docs/master_sl_table_01run_NOV2013.pdf)
(2) B qualified data were treated as nondetected chemicals because the chemical was detected in the associated blank and the estimated chemical concentration in the sample was not five times greater than the concentration in the associated blank (RAGS A, USEPA, 1989).
(3) Chromium can exist in the environment as chromium (III) and chromium (VI). The analytical results presented in this report are for chromium (total) and do not distinguish between the different valence states. It is assumed that total chromium is composed of chromium (VI) and chromium (III) in a 1 to 6 ratio. The estimated chromium (VI) concentration is calculated by dividing the maximum chromium (total) concentration measured in soil samples by 7. For the site concentration, the maximum chromium (total) concentration is 0.25 µg/L. Therefore, the estimated chromium (VI) concentration is 0.036 µg/L and the chromium (III) concentration is estimated as 0.21 µg/L.

5.4.1.5 MRS 11 North

No MC samples were collected in MRS 11 South, so no further evaluation is conducted.

Surface Soil

In support of the RI, a total of 28 surface soil samples were collected from MRS 11 North. Of these, 22 surface soil samples (PR-1011-S-001 through PR-1011-S-020, PR-1011-S-027, and PR-1011-S-028) were collected from DeE2 soils and 6 surface soil samples (PR-1011-S-021 through PR-1011-S-026) were collected from AmC2 soils. All samples were analyzed for explosives and eight metals. The analytical results are presented in Appendix C. Additionally, four soil samples from this area were collected and analyzed in the 2007 SI and those results were considered in this assessment.

The maximum detected concentration of each analyte is compared to PSVs in Table 5-10. Explosives were not detected in any of the soil samples collected at MRS 11 North. Therefore, explosives were not retained for further consideration in this risk assessment. The maximum detected concentration of seven metals (aluminum, barium, chromium, copper, lead, zinc, and antimony) did not exceed their respective PSVs. However, the maximum detected concentration of mercury (0.4 mg/kg) was detected in sample PR-1011-S-008 at a concentration greater than its PSV (0.1 mg/kg); therefore, mercury is considered a COPC and was retained for further consideration (see Appendix A: Figure A-29). Additional sampling to delineate mercury was not conducted since the private landowner could not be contacted to provide access to the property where step out samples would be placed. Additionally, the one soil sample with mercury detected at a concentration above its PSV was in close proximity of three other samples with mercury detected at concentrations below the PSV, therefore the mercury exceedance is considered a localized occurrence.

Surface water and Sediment

Surface water within the MRS is located in an area with no evidence of DoD impact and was sampled and used as a source of background data.

Groundwater

To evaluate the potential risk attributable to MC associated with exposure to groundwater in MRS 11 North, one groundwater sample (PR-CUL-GW-MRS-11-15) was collected from a newly installed monitoring well identified as Well 11-15 and analyzed for explosives, ammonium picrate, eight MC metals, perchlorate, chloride, and nitrate/nitrite as N. The analytical results are presented in Appendix C.

The groundwater flow in the vicinity of Well 11-15 is anticipated to flow to the northeast into Flamenco Lagoon. Well 11-15 is located less than 200 ft from the shoreline. High salinity and chloride concentrations in water at this location make the water unsuitable for consumption without desalination.

The maximum detected concentration of each analyte is compared to PSVs (if available) in Table 5-11. Explosives were not detected in any groundwater samples. The estimated maximum concentration of chromium (VI) (0.13 µg/L), which is equal to the maximum detected total chromium concentration divided by seven, exceeded its PSV (0.031 µg/L) (see Appendix A: Figure A-29). Chromium will be retained for further evaluation in the risk assessment.

Table 5-10: Soil Source Evaluation MRS 11 North

Analyte	Units	Maximum Detected Concentration		Soil Type	Back-ground mg/kg	Potential MC?	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Explosives - SW8330A										
1,3,5-Trinitrobenzene	mg/kg	< 0.200	U	DeE2	N/A	Yes	0.38	No	No	Not detected at MRS
1,3-Dinitrobenzene	mg/kg	< 0.200	U	DeE2	N/A	Yes	0.61	No	No	Not detected at MRS
2,4,6-Trinitrotoluene	mg/kg	< 0.200	U	DeE2	N/A	Yes	6.4	No	No	Not detected at MRS
2,4-Dinitrotoluene	mg/kg	< 0.200	U	DeE2	N/A	Yes	1.3	No	No	Not detected at MRS
2,6-Dinitrotoluene	mg/kg	< 0.200	U	DeE2	N/A	Yes	0.033	No	No	Not detected at MRS
2-Amino-4,6-dinitrotoluene	mg/kg	< 0.200	U	DeE2	N/A	Yes	10	No	No	Not detected at MRS
2-Nitrotoluene	mg/kg	< 0.200	U	DeE2	N/A	Yes	2.9	No	No	Not detected at MRS
3-Nitrotoluene	mg/kg	< 0.200	U	DeE2	N/A	Yes	0.61	No	No	Not detected at MRS
4-Amino-2,6-Dinitrotoluene	mg/kg	< 0.200	U	DeE2	N/A	Yes	3.6	No	No	Not detected at MRS
4-Nitrotoluene	mg/kg	< 0.200	U	DeE2	N/A	Yes	22	No	No	Not detected at MRS
Hexahydro-1,3,5-trinitro-1,3,5-triazine	mg/kg	< 0.200	U	DeE2	N/A	Yes	5.6	No	No	Not detected at MRS
Nitrobenzene	mg/kg	< 0.200	U	DeE2	N/A	Yes	1.3	No	No	Not detected at MRS
Nitroglycerin	mg/kg	< 0.200	U	DeE2	N/A	Yes	0.61	No	No	Not detected at MRS
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	mg/kg	< 0.200	U	DeE2	N/A	Yes	27	No	No	Not detected at MRS
PETN	mg/kg	< 1.000	U	DeE2	N/A	Yes	100	No	No	Not detected at MRS
Methyl-2,4,6-trinitrophenylnitramine (tetryl)	mg/kg	< 0.200	U	DeE2	N/A	Yes	0.99	No	No	Not detected at MRS

Analyte	Units	Maximum Detected Concentration		Soil Type	Back-ground mg/kg	Potential MC?	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Metals - SW6020A/SW3050B										
Aluminum	mg/kg	37,000		DeE2	**55,000**	Yes	55,000	No	No	Does not exceed PSV
Barium	mg/kg	150		DeE2	**710**	Yes	710	No	No	Does not exceed PSV
Chromium	mg/kg	12		DeE2	23	Yes	26	No	No	Does not exceed PSV
Copper	mg/kg	180	J	DeE2	**360**	Yes	360	No	No	Does not exceed PSV
Lead	mg/kg	21	J	DeE2	**98**	Yes	98	No	No	Does not exceed PSV
Zinc	mg/kg	100		DeE2	**350**	Yes	350	No	No	Does not exceed PSV
Antimony	mg/kg	0.80		DeE2	**1.2**	Yes	1.2	No	No	Does not exceed PSV
Mercury	mg/kg	0.40		DeE2	0.051	Yes	0.1	**Yes**	**Yes**	--

U = undetected at the stated reporting limit.

J - (Estimated, Bias Indeterminate): The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated due to non-conformances discovered during data validation.

Table 5-11: Groundwater Source Evaluation MRS 11 North

Analyte	Units	Maximum Detected Concentration		Potential MC?	PSV [1]	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Explosives - SW8330B								
1,3,5-Trinitrobenzene	µg/L	0.30	U	Yes	46	No	No	Not detected at MRS
1,3-Dinitrobenzene	µg/L	0.30	U	Yes	0.15	No	No	Not detected at MRS
2,4,6-Trinitrotoluene (TNT)	µg/L	0.30	U	Yes	0.76	No	No	Not detected at MRS
2,4-Dinitrotoluene	µg/L	0.30	U	Yes	0.20	No	No	Not detected at MRS
2,6-Dinitrotoluene	µg/L	0.30	U	Yes	0.042	No	No	Not detected at MRS
2-Amino-4,6-dinitrotoluene	µg/L	0.30	U	Yes	3.0	No	No	Not detected at MRS
2-Nitrotoluene	µg/L	0.30	U	Yes	0.27	No	No	Not detected at MRS
3-Nitrotoluene	µg/L	0.30	U	Yes	0.13	No	No	Not detected at MRS
4-Amino-2,6-Dinitrotoluene	µg/L	0.30	U	Yes	3.0	No	No	Not detected at MRS
4-Nitrotoluene	µg/L	0.30	U	Yes	3.7	No	No	Not detected at MRS
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	µg/L	0.30	U	Yes	0.61	No	No	Not detected at MRS
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	µg/L	0.30	U	Yes	6.1	No	No	Not detected at MRS
Nitrobenzene	µg/L	0.30	U	Yes	0.12	No	No	Not detected at MRS
Nitroglycerin	µg/L	0.30	U	Yes	0.15	No	No	Not detected at MRS
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	µg/L	0.30	U	Yes	78	No	No	Not detected at MRS
Pentaerythritol Tetranitrate (PETN)	µg/L	1.5	U	Yes	3.0	No	No	Not detected at MRS
Ammonium Picrate - SW8321A								
Ammonium picrate	µg/L	0.12	U	Yes	NA	No	No	Not detected at MRS
Total Metals - SW6020A /7470A								
Aluminum	µg/L	1100		Yes	1,600	No	No	Does not exceed PSV
Antimony	µg/L	0.50	U	Yes	0.60	No	No	Not detected at MRS
Barium	µg/L	8.1		Yes	290	No	No	Does not exceed PSV

Analyte	Units	Maximum Detected Concentration	Potential MC?	PSV [1]	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Chromium(total)	µg/L	0.90	Yes	NA	N/A	N/A	N/A
Chromium(III) [2]	µg/L	0.77	Yes	1,600	No	No	Does not exceed PSV
Chromium(VI) [2]	µg/L	0.13	Yes	0.031	Yes	**Yes**	--
Copper	µg/L	27	Yes	62	Yes	No	Does not exceed PSV
Lead	µg/L	1.2	Yes	15	No	No	Does not exceed PSV
Mercury	µg/L	0.15 U	Yes	0.43	No	No	Not detected at MRS
Zinc	µg/L	95	Yes	470	No	No	Does not exceed PSV
Perchlorate - SW6850							
Perchlorate	µg/L	0.32 J	Yes	1.1	No	No	Does not exceed PSV

(NO CODE) - Confirmed identification.

U - Analyte was analyzed for but not detected above the limit of detection (LOD).

J - (Estimated, Bias Indeterminate): The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated due to non-conformances discovered during data validation.NA - Screening criterion not available

N/A - Not Applicable

(1) USEPA RSLs for Tapwater (Target Risk = 10-6; Hazard Quotient = 0.1), November 2013. (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/docs/master_sl_table_01run_NOV2013.pdf)

(2) Chromium can exist in the environment as chromium (III) and chromium (VI). The analytical results presented in this report are for chromium (total) and do not distinguish between the different valence states. It is assumed that total chromium is composed of chromium (VI) and chromium (III) in a 1 to 6 ratio. The estimated chromium (VI) concentration is calculated by dividing the maximum chromium (total) concentration measured in soil samples by 7. For the site concentration, the maximum chromium (total) concentration is 0.90 µg/L. Therefore, the estimated chromium (VI) concentration is 0.13 µg/L and the chromium (III) concentration is estimated as 0.77 µg/L.

5.4.1.6 MRS 13

Surface Soil

In support of the RI, 32 surface soil samples (PR-1013-S-038 through PR-1013-S-069) were collected at the beaches of MRS 13 and analyzed for explosives and eight metals. All were collected in Cm soil type. The analytical results are presented in Appendix C. Additionally, two soil samples from this area were collected in October 2016 and analyzed for the 2007 SI and those results were considered in this assessment. SI sample CUL-13-SS-06-01 was collected from the AmC2 soil type, and CUL-13-SS-06-02 was collected from the DeE2 soil type.

The maximum detected concentration of each analyte is compared to PSVs in Table 5-12. Explosives were not detected in any of the soil samples collected at MRS 13. Therefore, explosives were not retained for further consideration in this risk assessment. The remaining metals did not exceed their respective PSVs and were also not retained for further evaluation in this risk assessment. Although the maximum detected concentrations of analytes at MRS 13 were in samples collected in AmC2 and DeE2 soils, the maximum detected concentrations of metals in samples collected in Tf soils at MRS 13 also did not exceed their respective PSVs. Therefore, metals were not retained for further consideration in this risk assessment.

Surface Water/Sediment

There is no perennial surface water present on the MRS, therefore the surface water/sediment pathway is incomplete.

Groundwater

According to the USGS 2014, *Hydrogeology of Puerto Rico and the Outlying Islands of Vieques, Culebra and Mona*, when evaluating the aquifers in the outlying islands of Vieques, Culebra, and Mona, only Vieques was reported to be underlain by aquifers of any local importance. No aquifers were identified on Cayo Luis Peña (MRS 13). Figure 5-1 identifies the locations of Culebra aquifers to include Cayo Luis Peña in which none are expected to exist. Therefore if no groundwater is suspected to exist, there is no MC source and there are no receptors present, the groundwater pathway is incomplete.

Table 5-12: Soil Source Evaluation MRS 13

Analyte	Units	Maximum Detected Concentration		Soil Type	Potential MC?	Back-ground mg/kg	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Explosives - SW8330B										
1,3,5-Trinitrobenzene	mg/kg	< 0.200	U	Cm	Yes	N/A	0.38	No	No	Not detected at MRS
1,3-Dinitrobenzene	mg/kg	< 0.200	U	Cm	Yes	N/A	0.61	No	No	Not detected at MRS
2,4,6-Trinitrotoluene	mg/kg	< 0.200	U	Cm	Yes	N/A	6.4	No	No	Not detected at MRS
2,4-Dinitrotoluene	mg/kg	< 0.200	U	Cm	Yes	N/A	1.3	No	No	Not detected at MRS
2,6-Dinitrotoluene	mg/kg	< 0.200	U	Cm	Yes	N/A	0.033	No	No	Not detected at MRS
2-Amino-4,6-dinitrotoluene	mg/kg	< 0.200	U	Cm	Yes	N/A	10	No	No	Not detected at MRS
2-Nitrotoluene	mg/kg	< 0.200	U	Cm	Yes	N/A	2.9	No	No	Not detected at MRS
3-Nitrotoluene	mg/kg	< 0.200	U	Cm	Yes	N/A	0.61	No	No	Not detected at MRS
4-Amino-2,6-Dinitrotoluene	mg/kg	< 0.200	U	Cm	Yes	N/A	3.6	No	No	Not detected at MRS
4-Nitrotoluene	mg/kg	< 0.200	U	Cm	Yes	N/A	22	No	No	Not detected at MRS
Hexahydro-1,3,5-trinitro-1,3,5-triazine	mg/kg	< 0.200	U	Cm	Yes	N/A	5.6	No	No	Not detected at MRS
Nitrobenzene	mg/kg	< 0.200	U	Cm	Yes	N/A	1.3	No	No	Not detected at MRS
Nitroglycerin	mg/kg	< 0.200	U	Cm	Yes	N/A	0.61	No	No	Not detected at MRS
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	mg/kg	< 0.200	U	Cm	Yes	N/A	27	No	No	Not detected at MRS
PETN	mg/kg	< 1.000	U	Cm	Yes	N/A	100	No	No	Not detected at MRS
Methyl-2,4,6-trinitrophenylnitramine (tetryl)	mg/kg	< 0.200	U	Cm	Yes	N/A	0.99	No	No	Not detected at MRS
Metals - SW6020A/SW3050B, 7471B										
Aluminum	mg/kg	49,000 (1)		DeE2	Yes	55,000	55,000	No	No	Does not exceed PSV
Barium	mg/kg	110 (1)		DeE2	Yes	710	710	No	No	Does not exceed PSV

Analyte	Units	Maximum Detected Concentration		Soil Type	Potential MC?	Back-ground mg/kg	PSV mg/kg	Exceeds PSV?	Further Evaluation Required?	Primary Reason for Exclusion From Evaluation
Chromium	mg/kg	17 (1)		DeE2	Yes	23	26	No	No	Does not exceed PSV
Copper	mg/kg	94 (1)		DeE2	Yes	360	360	No	No	Does not exceed PSV
Lead	mg/kg	8.6		Cm	Yes	3.2	30	No	No	Does not exceed PSV
Zinc	mg/kg	74 (1)		DeE2	Yes	350	350	No	No	Does not exceed PSV
Antimony	mg/kg	0.14	J	Cm	Yes	0.3	3.1	No	No	Does not exceed PSV
Mercury	mg/kg	0.048 (1)		AmC2	Yes	0.048	0.1	No	No	Does not exceed PSV

U = undetected at the stated reporting limit.

J = (Estimated, Bias Indeterminate): The compound or analyte was analyzed for and positively identified by the laboratory; however the reported concentration is estimated due to non-conformances discovered during data validation.

(1) Maximum detected concentrations from the 2007 SI Report (Parsons, 2007)

5.5 REVISED CSM

5.5.1 CSM

CSMs evaluate the potential presence or absence of migration/exposure pathways and receptors, based on site-specific conditions. It is necessary to evaluate site-specific conditions and land use to evaluate risks posed to potential receptors under current and future land use scenarios. Exposure pathways for all relevant media are evaluated. The CSMs for the Culebra Island MRSs summarize which potential exposure pathways for receptors are (or may be) complete and which are (and are likely to remain) incomplete. An exposure pathway is not considered to be complete unless all four of the following elements are present (USEPA, 1989):

- A source of contamination
- An environmental transport and/or exposure medium
- A point of exposure at which the contaminant can interact with a receptor
- A receptor and a likely route of exposure at the exposure point.

If any single factor listed above is not present, the pathway would be incomplete. An incomplete pathway indicates that there are no means by which a receptor (human or ecological) can come in contact with either MC or MEC. Therefore, no risk would be expected from that exposure pathway.

As part of the TPP process, the TPP Team developed a CSM that included each of the eight investigation areas based on information available at the time (Appendix Q of the WP). The CSM developed in support of the TPP process is presented in Chapter 3 (Figures 3-1 through 3-6). A CSM is a dynamic document that is to be evaluated and revised each time new information is received. As an SI was completed for this site, the initial CSMs for this RI were based on the SI findings (Parsons, 2007). Based on the results of the contaminant characterizations conducted for each MRS, the initial CSM described in Subsection 3.1 was reviewed and updated to reflect newly established MRSs, potentially complete pathways, and any MC detected above screening criteria (COPCs). The following figures present the revised CSM for the Culebra Island MRSs:

- Figure 5-2: Revised CSM for MRS 06 North
- Figure 5-3: Revised CSM for MRS 06 South
- Figure 5-4: Revised CSM for MRS 08
- Figure 5-5: Revised CSM for MRS 09
- Figure 5-6: Revised CSM for MRS 10
- Figure 5-7: Revised CSM for MRS 11 North
- Figure 5-8: Revised CSM for MRS 11 South
- Figure 5-9: Revised CSM for MRS 13.

The following Ecological Conceptual Site Models (ECSM) have been separated and revised from the previous CSMs found in Figures 3-1 through 3-6:

- Figure 5-10: Revised ECSM for MRS 06 North

- Figure 5-11: Revised ECSM for MRS 06 South
- Figure 5-12: Revised ECSM for MRS 08
- Figure 5-13: Revised ECSM for MRS 09
- Figure 5-14: Revised ECSM for MRS 10
- Figure 5-15: Revised ECSM for MRS 11
- Figure 5-16: Revised ECSM for MRS 13.

5.5.2 Land Use

Current and future land use for each Culebra Island MRS is described in Subsection 2.2.11.

5.5.3 MEC Exposure Pathways

The following paragraphs evaluate the potential exposure pathways for MEC/MD at each MRS. CSMs depicting these pathways, presented for MRSs 06, 08, 09, 10, 11, and 13, are shown in Figures 5-2 through 5-16, respectively.

5.5.3.1 MRS 06 Artillery Firing Area

Four subsurface MD items were found in Grids 06-03 and 06-17. Two artillery primers (specific type unidentifiable) were recovered at 2 to 3 inches bgs. Two pieces of unidentified MD (fragments) were recovered at a depth of 2 inches bgs. Although the specific munition types were not identified, they were likely from HE items (most likely projectiles and not munitions equipped with sensitive fuzing such as submunitions) landing in adjacent MRSs. These two MD items are considered isolated pieces of munitions fragments that may be from munitions some distance away, so their presence does not necessarily indicate a significant hazard. Because the few MD items were anomalous to this MRS, the RI has concluded there are no unacceptable MEC Hazards. The negligible hazard to site users is acceptable.

5.5.3.2 MRS 08 Cayo Norte Impact Area

Thirteen MD items were recovered in six grids within MRS 08 (Grids 08-02, 08-03, 08-06, 08-07, 08-08, and 08-09). All 13 MD items were identified to be fragmentation from 75 mm projectiles (shrapnel, rotating bands, fuzes, and a base plate) and were recovered 0 to 3 inches bgs. The 75mm is considered an HE item, and not sensitive. Based on the anticipated continued development of this area, and the limited access (access by boat only and the steep rugged terrain), the surface and subsurface MEC exposure pathway is considered complete for MRS 08.

5.5.3.3 MRS 09 Soldado Point Mortar And Bombing Area

Seven MD items were recovered 0 to 3 inches bgs in three grids (09-04, 09-07, and 09-13) within MRS 09. The items consisted of fragmentation, fuzes, and a base plate. Although the specific munition types were not identified, they were likely from HE items. No MEC related to military use was found in the MRS. Based on the anticipated continued recreational use of beach areas, and the limited access (steep rugged terrain), the surface and subsurface the historical findings of munitions used and the discovery of MD the MEC exposure pathway is considered complete for MRS 09.

5.5.3.4 MRS 10 Defensive Firing Area No. 1

No MEC or MD items were recovered within the upland grids or along the beach areas of MRS 10. Based on the absence of MEC on the surface and subsurface, the MEC exposure pathway is considered incomplete for MRS 10.

5.5.3.5 MRS 11 Defensive Firing Area No. 2 North

Fifteen MD items were recovered 0 to 4 inches bgs in the upland grids (11-13, 11-14, 11-15, 11-16, and 11-17) and two MD items were recovered 0 to 3 inches bgs from beach transects (11M-08 and 11M-11). Although the specific munition types were not identified, they were considered to be indicators of the presence of HE items. Based on the anticipated continued development and recreational use of this area, and the limited access (steep and rugged terrain), the surface and subsurface MEC exposure pathway is considered complete for MRS 11 North.

5.5.3.6 MRS 11 Defensive Firing Area No. 2 South

As previously mentioned, no MEC or MD items were recovered in the southern portion of MRS 11. The RI concluded there is no unacceptable MEC hazard present for residents, recreational users, construction workers, or site visitors within the 498.2 acres of MRS 11 South.

5.5.3.7 MRS 13 Cayo Luis Peña Impact Areas

Ten MD items and two expended small arms ammunition items were recovered 0 to 18 inches bgs within MRS 13 beach areas. Additionally, during surface reconnaissance from a 2009 post award site visit on unestablished trails, MD from 105mm projectiles (1-HE, 1-illumination, 4-unidentified), 5-inch projectiles (31), 3-inch projectiles (3), flares (8), fuzes, and other MD pieces was observed at 112 locations. Based on the anticipated continued recreational use of this area, and the limited access (access by boat only, and the steep and rugged terrain), the surface and subsurface MEC exposure pathway is considered complete for MRS 13.

5.5.4 MC Exposure Pathways

The following sections evaluate the potential exposure pathways for MC at the Culebra Island MRSs. The CSMs and ECSMs depicting these pathways are presented in Figures 5-2 through 5-16.

Note: Based on USACE experience from investigations of MC at many FUDS sites at many MRSs, unacceptable MC contamination was detected in soil, and there is no source to migrate to groundwater. To support the logic that if no source is present in soil, there will be no migration to groundwater, existing wells were evaluated for potential sampling, wells were installed and groundwater sampling was conducted.

5.5.4.1 Potential Receptors

5.5.4.1.1 MRS 06 (North and South)

The majority of MRS 06 is comprised of private residences; other areas contain undeveloped tracts that are steep with heavy vegetation. Potential receptors include residents, construction workers, onsite workers, recreational users, and trespassers. Potential ecological receptors include plants and soil invertebrates; insectivores/herbivorous birds and mammals; carnivorous

birds and mammals; aquatic birds; and reptiles and amphibians. In the lagoon, plants, reptiles and amphibians, fish and benthic invertebrates may be present.

Sensitive ecological receptors are identified in Chapter 2, and include (with habitat) the leatherback turtle (beaches), hawksbill turtle (beaches), Virgin Islands tree boa (forest with continuous canopy and abundant anoles), Grant's leptocereus (non-forest and forest).

Because one COPC, barium, was identified in the surface soil at MRS 06 North (Section 5.4.1.1), the surface soil exposure pathways are potentially complete for humans (residents, site visitors, trespassers, construction workers, and recreational users) and ecological receptors. The subsurface soil was not sampled. The subsurface soil exposure pathways are considered potentially complete for barium for construction workers who would come into contact with subsurface soil during excavation activities. The ingestion of biota exposure pathways are potentially complete for residents, site visitors, trespassers, and recreational users.

In MRS 06 North, the exposure pathways are complete for plants and soil invertebrates; insectivores/herbivorous birds and mammals; carnivorous birds and mammals; aquatic birds; and reptiles and amphibians. Exposure routes include uptake/direct contact, incidental ingestion, and food chain transfer. The exposure routes for each receptor are shown on Figure 5-10.

One lagoon located in the northern portion of MRS 06 exists within a property in which ROE was refused (see Appendix A: Figure A-31). Although lack of access to the surface water and sediment prevented sampling, investigation in nearby parcels indicated no evidence of MEC, and no evidence of high concentrations of MD. Sampling is not necessary to characterize the lagoon. The lack of a source indicates MC contamination is improbable in the surface water and sediment. Therefore, the surface water and sediment exposure pathways are incomplete for human and ecological receptors.

No COPCs were detected in the groundwater at MRS 06 North. Therefore, the groundwater exposure pathways are incomplete for human receptors. Ecological receptors are not exposed to groundwater. Therefore, the groundwater exposure pathways are incomplete for ecological receptors.

No COPCs were identified in the surface soil at MRS 06 South (Section 5.4.1.2). Therefore, the soil exposure pathways are incomplete for human and ecological receptors.

No perennial surface water is present at MRS 06 South. Therefore, the surface water and sediment exposure pathways are incomplete for human and ecological receptors.

One COPC (MC metal chromium) exceeded its screening value in groundwater at MRS 06 South and was carried forward for further evaluation to satisfy the concerns of regulators.

5.5.4.1.2 MRS 08

MRS 08 is a privately owned island. Potential receptors include residents, construction workers, onsite workers, recreational users, and trespassers. Potential ecological receptors include plants and soil invertebrates; insectivores/herbivorous birds and mammals; carnivorous birds and mammals; aquatic birds; and reptiles and amphibians. In the lagoon on the southwest side, plants, reptiles and amphibians, fish and benthic invertebrates may be present.

Sensitive ecological receptors are identified in Chapter 2, and include (with habitat) the leatherback turtle (beaches), hawksbill turtle (beaches), Virgin Islands tree boa (forest with

continuous canopy and abundant anoles), Culebra giant anole (mature forest), and Culebrita water willow (coastal scrub shrub).

No COPCs were identified in the surface soil at MRS 08 (Section 5.4.1.3). Therefore, the soil exposure pathways are incomplete for human and ecological receptors.

No perennial surface water is present at MRS 08. Therefore, the surface water exposure pathways are incomplete for human and ecological receptors.

No COPCs were identified in the sediment at MRS 08. Therefore, the sediment exposure pathways are incomplete for human and ecological receptors.

There are no wells within MRS 08, and there is no evidence groundwater has been used as a source of potable water. Therefore, the groundwater exposure pathways are incomplete for human receptors. Ecological receptors are not exposed to groundwater. Since there is no surface soil source for MC, the groundwater exposure pathways are incomplete for human and ecological receptors.

5.5.4.1.3 MRS 09

The majority of MRS 09 is managed by the PRDNER. Other areas contain small residences. Potential current and future receptors include residents, construction workers, onsite workers, recreational users, and trespassers. Potential ecological receptors include plants and soil invertebrates; insectivores/herbivorous birds and mammals; carnivorous birds and mammals; aquatic birds; and reptiles and amphibians. In the lagoons, plants, reptiles and amphibians, fish and benthic invertebrates may be present.

Sensitive ecological receptors are identified in Chapter 2, and include (with habitat) the hawksbill turtle (beaches), and Grant's leptocereus (non-forest and forest). No COPCs were identified in the surface soil at MRS 09 (Section 5.4.1.4). Therefore, the soil exposure pathways are incomplete for human and ecological receptors.

COPCs were identified in the sediment in MRS 09 and therefore the exposure pathways are complete for plants, reptiles and amphibians, fish and benthic invertebrates. Exposure routes include uptake/direct contact, incidental ingestion, and food chain transfer. The exposure routes for each receptor are shown on Figure 5-13.

The results for tetryl in the demolition soil samples (PR-0009-CPRE, PR-0010-CPRE, PR-0011-CPRE, PR-0012-CPRE, PR-0013-CPST, PR-0014-CPST, PR-0015-CPST, and PR-0016-CPST) collected from the second demolition at the one demolition site used in MRS 09 were rejected. Therefore no analytical results are available to represent the concentration of tetryl at the demolition site. Therefore, the soil exposure pathways are potentially complete for human and ecological receptors.

No COPCs were identified in the surface water at MRS 09. Therefore, the surface water exposure pathways are incomplete for human and ecological receptors.

Two COPCs (MC metals aluminum and copper) were identified in the sediment at MRS 09. Therefore, the sediment exposure pathways are potentially complete for human and ecological receptors.

Two COPCs (MC metals copper and chromium) exceeded their screening value in the groundwater at MRS 09 and were carried forward for further evaluation to satisfy the concerns

of regulators. Ecological receptors are not exposed to groundwater. Therefore, the groundwater exposure pathways are incomplete for ecological receptors.

5.5.4.1.4 MRS 10

The majority of MRS 10 is comprised of private residences and commercial areas. Other areas contain undeveloped tracts that are steep with heavy vegetation. Potential current and future receptors include residents, construction workers, onsite workers, recreational users, and trespassers. Potential ecological receptors include plants and soil invertebrates; insectivores/herbivorous birds and mammals; carnivorous birds and mammals; aquatic birds; and reptiles and amphibians. No lagoons are present in MRS 10.

Sensitive ecological receptors include species identified in Chapter 2, and include (with habitat) the hawksbill turtle (beaches), Virgin Islands tree boa (forest with continuous canopy and abundant anoles), Culebra giant anole (mature forest), Grant's leptocereus (non-forest and forest) and Wheeler's peperomia (forest).

Environmental samples were not collected in MRS 10 since no MD was discovered during the RI fieldwork. Given the lack of MD, and no evidence of concentrated munitions use, it is reasonable to state that there are no human health and ecological risks related to the use of munitions at MRS 10. There are no complete MC exposure pathways at MRS 10.

5.5.4.1.5 MRS 11 (North and South)

The majority of MRS 11 is comprised of private residences and industrial areas. Other areas contain undeveloped tracts that are steep with heavy vegetation. Potential current and future receptors include residents, construction workers, onsite workers, recreational users, and trespassers. Potential ecological receptors include plants and soil invertebrates; insectivores/herbivorous birds and mammals; carnivorous birds and mammals; aquatic birds; and reptiles and amphibians. In the lagoon, plants, reptiles and amphibians, fish and benthic invertebrates are present.

Sensitive ecological receptors include species identified in Chapter 2, and include (with habitat) the hawksbill turtle (beaches), Virgin Islands tree boa (forest with continuous canopy and abundant anoles), Culebra giant anole (mature forest), Grant's leptocereus (non-forest and forest) and Wheeler's peperomia (forest).

In MRS 11 North, the exposure pathways are complete for plants and soil invertebrates; insectivores/herbivorous birds and mammals; carnivorous birds and mammals; aquatic birds; and reptiles and amphibians. Exposure routes include uptake/direct contact, incidental ingestion, and food chain transfer. The exposure routes for each receptor are shown on Figure 5-15. Because one COPC was identified in the surface soil at MRS 11 (Section 5.4.1.5), the surface soil exposure pathways are potentially complete for human and ecological receptors. The subsurface soil exposure pathways are potentially complete for construction workers who would come into contact with subsurface soil during excavation activities. Exposure pathways based on the ingestion of biota are potentially complete for residents, site visitors, trespassers, and recreational users.

Surface water within MRS 11 is located in an area with no evidence of DoD impact. Therefore, the surface water and sediment exposure pathways are incomplete for human and ecological receptors.

One COPC (MC metal chromium) exceeded its screening value in the groundwater at MRS 11 and was carried forward for further evaluation to satisfy the concerns of regulators. Ecological receptors are not exposed to groundwater. Therefore, the groundwater exposure pathways are incomplete for ecological receptors.

5.5.4.1.6 MRS 13

MRS 13 is an island that is managed by USFWS and is undeveloped with steep terrain and heavy vegetation. Potential current and future receptors include onsite workers and recreational users. Potential ecological receptors include plants and soil invertebrates; insectivores/herbivorous birds and mammals; carnivorous birds and mammals; aquatic birds; and reptiles and amphibians. In the beach and protected inlet areas, plants, reptiles and amphibians, fish and benthic invertebrates may be present.

Sensitive ecological receptors are identified in Chapter 2, and include (with habitat) the leatherback turtle (beaches), hawksbill turtle (beaches), Virgin Islands tree boa (forest with continuous canopy and abundant anoles), Culebra giant anole (mature forest), Culebrita water willow (coastal scrub shrub), Grant's leptocereus (non-forest and forest), and Wheeler's peperomia (forest).

No COPCs were identified in the surface soil at MRS 13 (Section 5.4.1.6). Therefore, the soil exposure pathways are incomplete for human and ecological receptors.

No perennial surface water is present at MRS 13. Therefore, the surface water exposure pathways are incomplete for human and ecological receptors.

No groundwater is suspected to exist and there are no human receptors present. Therefore, the groundwater pathway is incomplete for human receptors. Ecological receptors are not exposed to groundwater. Therefore, the groundwater exposure pathways are incomplete for ecological receptors.

5.5.4.2 Potential Exposure Pathways for Human and Ecological Receptors

Potential exposure pathways to human receptors are presented below and summarized on the CSMs presented in Figures 5-2 through 5-9. Potential exposure pathways to ecological receptors are presented below and summarized on the CSMs presented in Figures 5-10 through 5-16.

5.5.4.2.1 Surface and Sub-Surface Soil

Potential exposure to MC contamination in soil could occur through the following pathways:

- Incidental ingestion of soil
- Dermal contact with soil
- Inhalation of re-suspended particulate matter from soil.

All potential human receptors previously mentioned for each Culebra Island MRS could interact with the pathways mentioned above. Potential ecological receptors exist in all Culebra Island

MRSs, which could be potentially affected through the ingestion and dermal contact pathways. While ecological receptors may also be affected through inhalation of re-suspended particulate matter, exposure parameters are generally not available to quantitatively evaluate the pathway. Therefore, the inhalation pathway is qualitatively evaluated for ecological receptors. Very little sub-surface soil is present on the island and none was encountered in the MEC investigation, beyond the highly dynamic beach areas. Therefore, the sub-surface pathway was not evaluated.

5.5.4.2.2 Surface Water and Sediment

Due to runoff from the surrounding areas, surface water and sediment are present within some of the Culebra Island MRSs. Potential exposure to MC contamination in surface water and sediment could occur through the following pathways:

- Incidental ingestion of surface water or sediment
- Dermal contact with surface water or sediment.

All potential human receptors previously mentioned for each Culebra Island MRS could interact with the pathways mentioned above. Potential ecological receptors exist in all Culebra Island MRSs, which could be potentially affected through the ingestion and dermal contact pathways.

5.5.4.3 Groundwater

While releases of MC directly to groundwater is not expected due to the depth of groundwater at the site compared to the penetration depth of ordnance used at the site, there is a potential for MC to migrate from soil to groundwater. Despite the fact that groundwater use is not expected or feasible at many areas on site, Puerto Rico's WQS Regulation, classifies all groundwater as potable. Therefore, future water wells could, in theory, be permitted and installed to supply residents of Culebra Island. While unlikely, potential exposure to MC contamination in groundwater could occur through the following pathways:

- Incidental ingestion of groundwater
- Ingestion of groundwater as drinking water
- Dermal exposure to groundwater.

Potential receptors of these pathways include:

- Current and future residents
- Current and future commercial and industrial workers
- Current and future excavation and construction workers.

Currently, no complete pathway exists for ecological receptors with regard to groundwater.

5.5.4.4 Incomplete Pathways

Inhalation of volatile compounds by on-site receptors was evaluated and considered incomplete for human and ecological receptors at the Culebra Island MRSs.

Inhalation of VOCs from soil or groundwater, or vapor intrusion of Volatile Organic Compounds (VOCs) from groundwater into buildings are incomplete exposure pathways, as no volatile compounds are MC of the munitions discovered during the RI.

The groundwater survey conducted in 2013 did not find any evidence that groundwater was in use as a drinking water source. Previous studies have noted that the five existing PRASA wells cannot meet island water demand, and there is no reason to suspect the current supply of drinking water piped in from the Puerto Rico mainland will change. A permit is required before installation of any new wells. For MRS 08, the absence of permanent residences, the small acreage of the island which would be significantly impacted by saltwater intrusion and the volcanic nature of the island with groundwater storage in fractures, coupled with logistical challenges for drilling equipment, indicate future groundwater use is unlikely. For MRS 13 no residences are present onsite and will not be present in the future.

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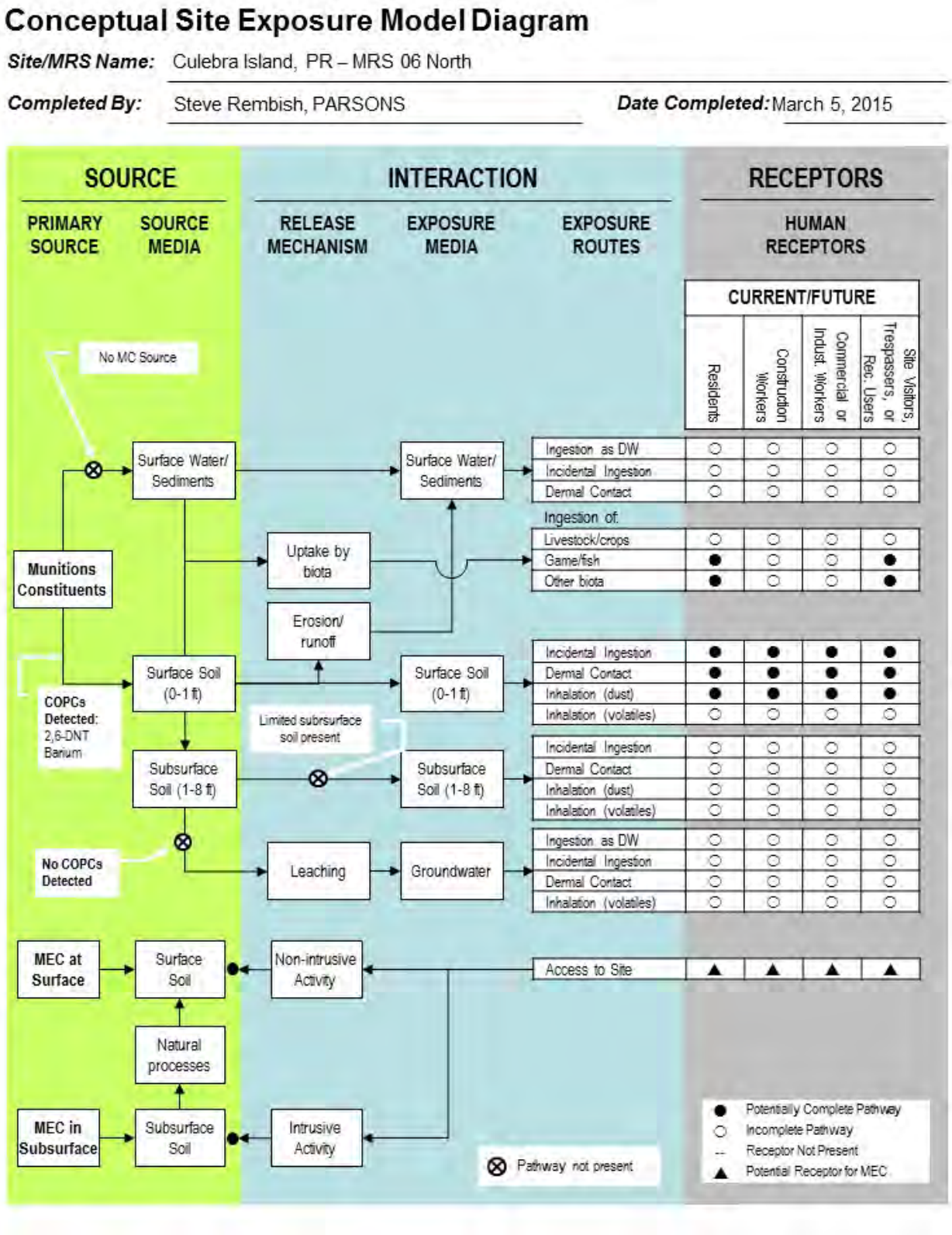

Figure 5-2: Revised CSM for MRS 06 North

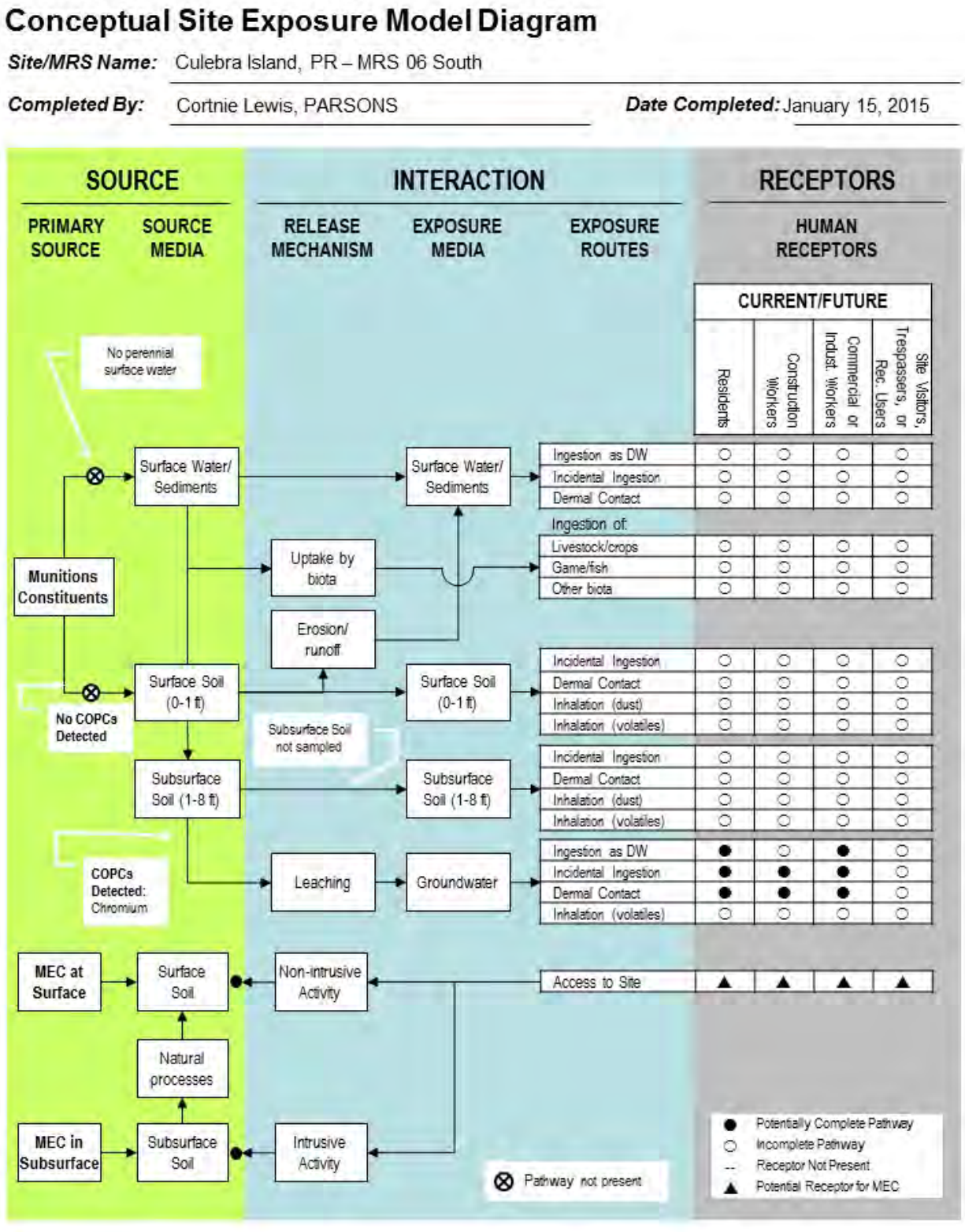

Figure 5-3: Revised CSM for MRS 06 South

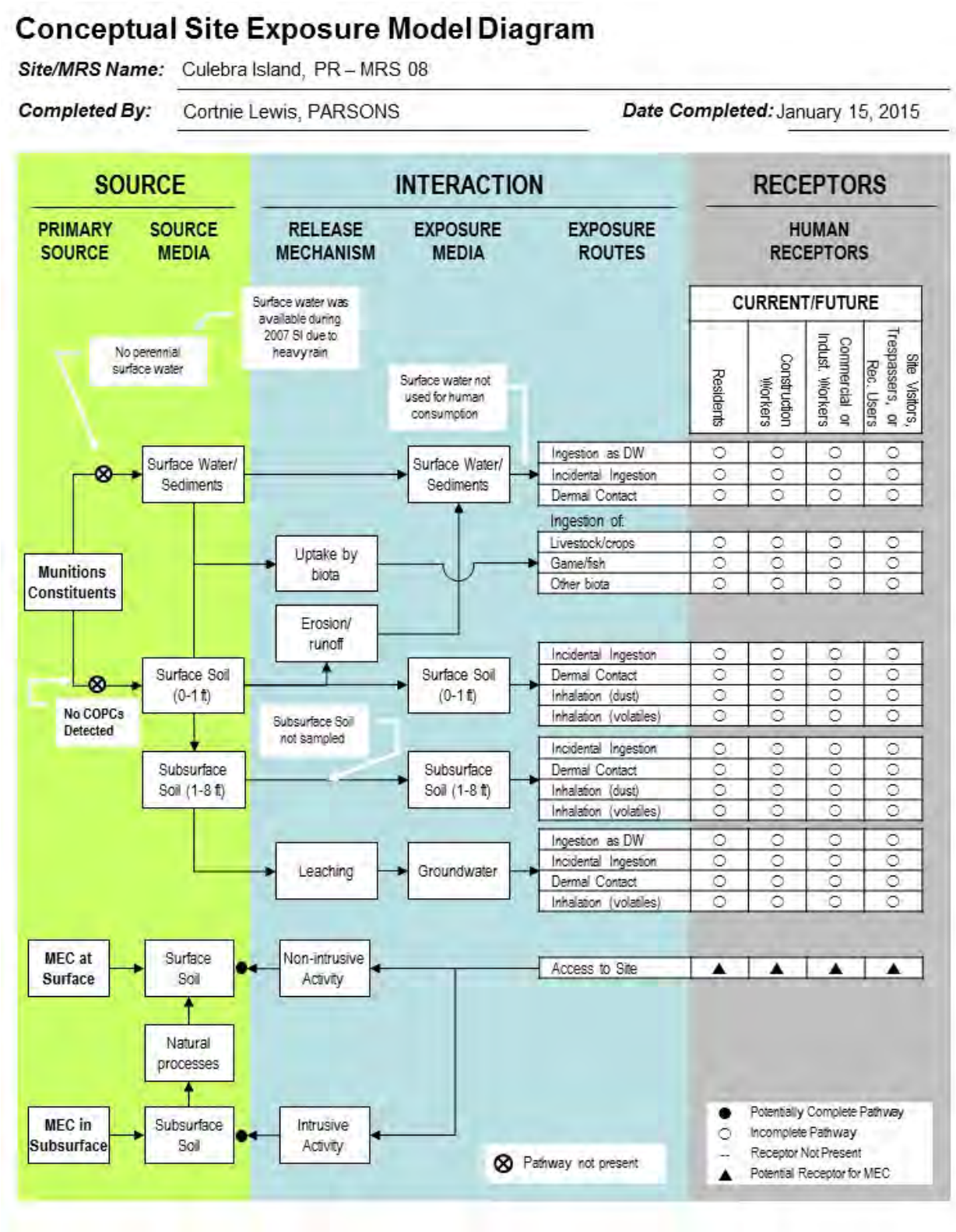

Figure 5-4: Revised CSM for MRS 08

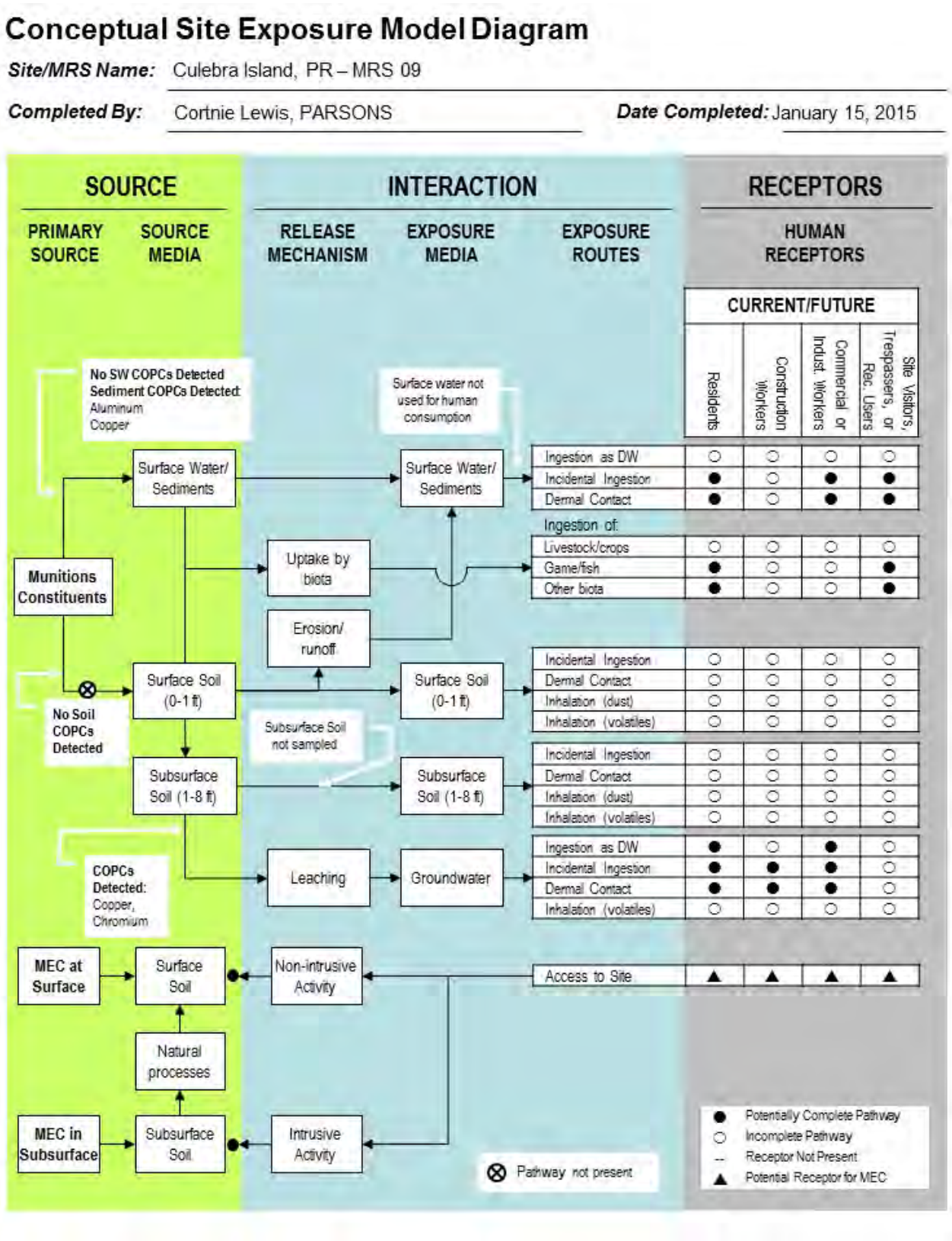

Figure 5-5: Revised CSM for MRS 09

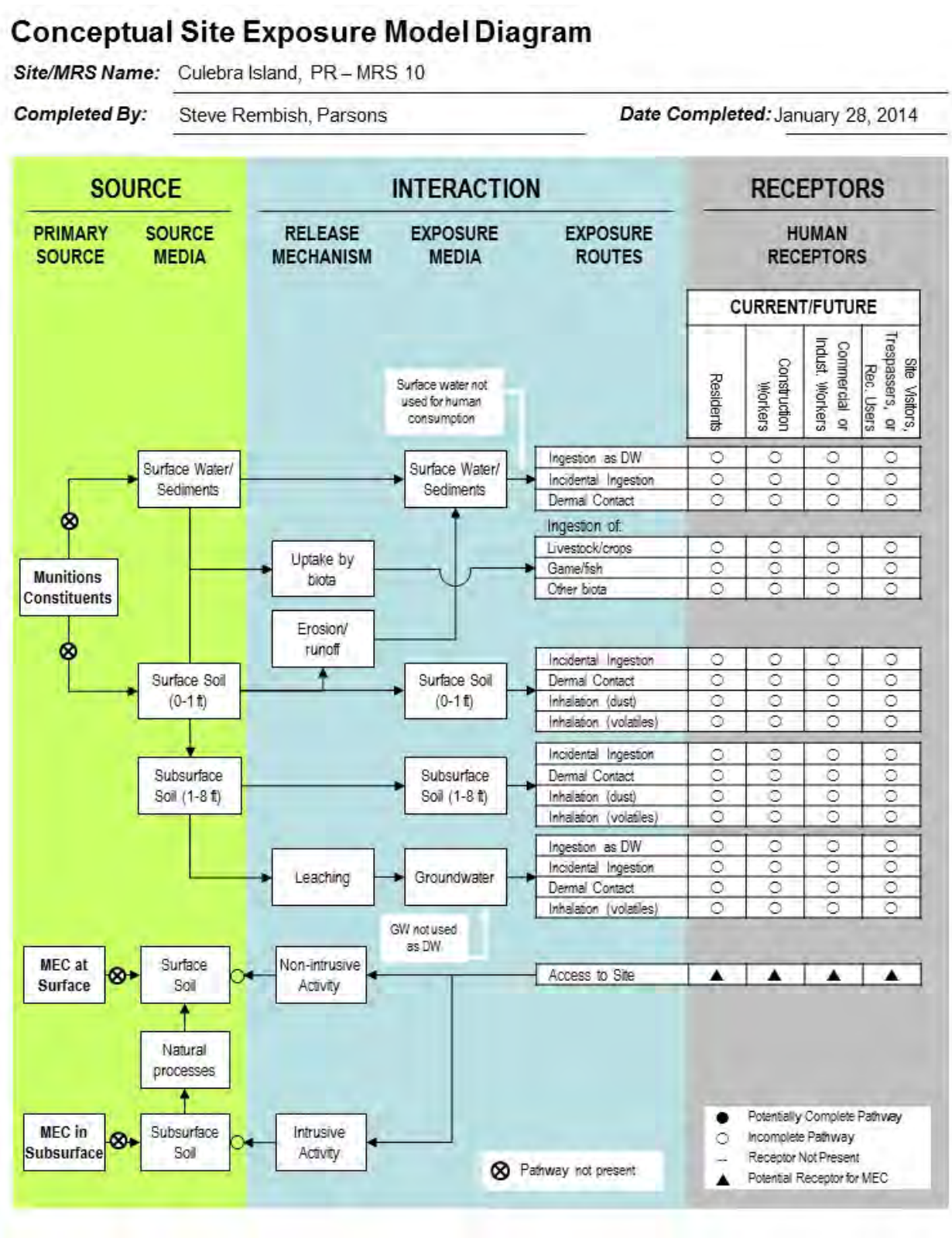

Figure 5-6: Revised CSM for MRS 10

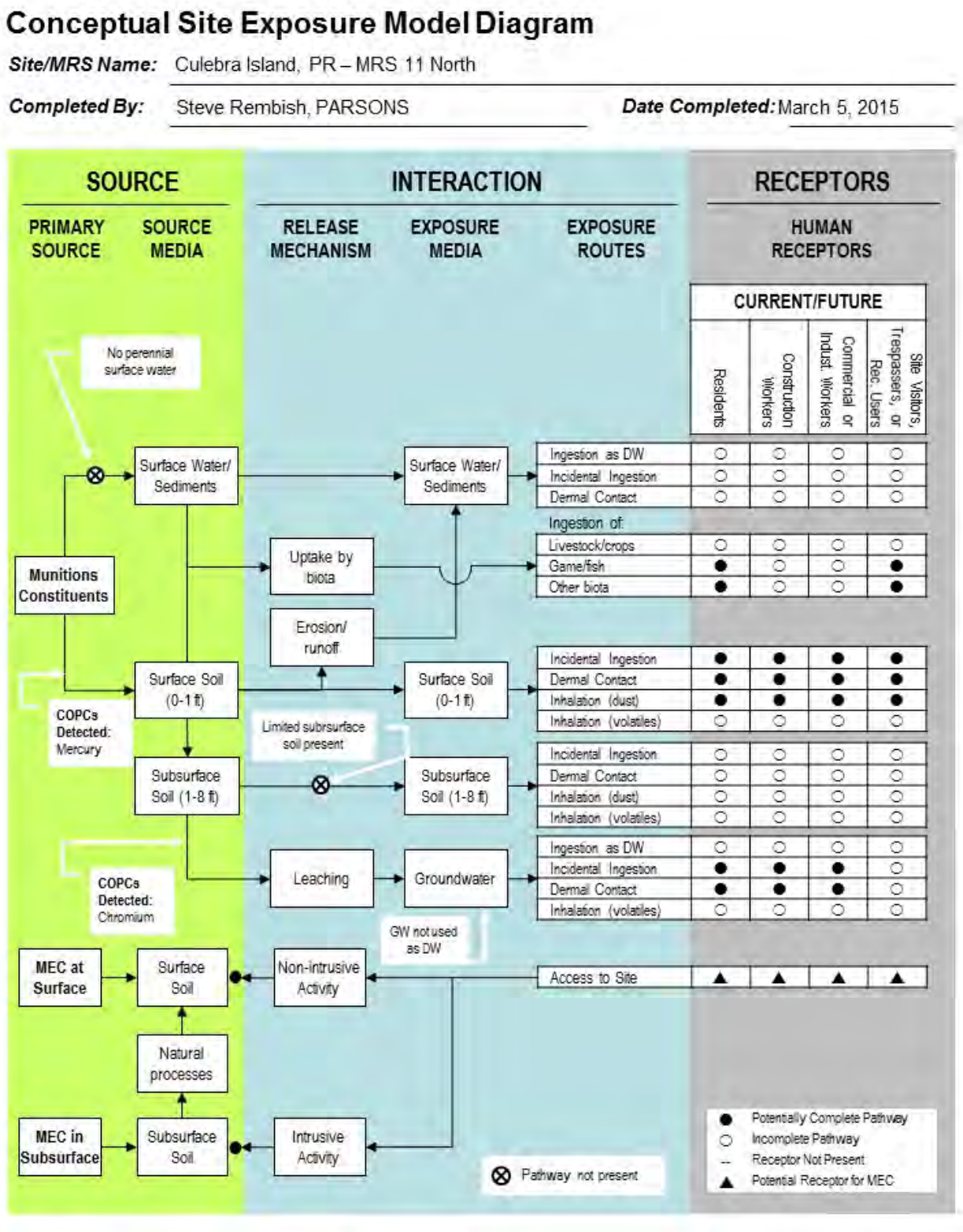

Figure 5-7: Revised CSM for MRS 11 North

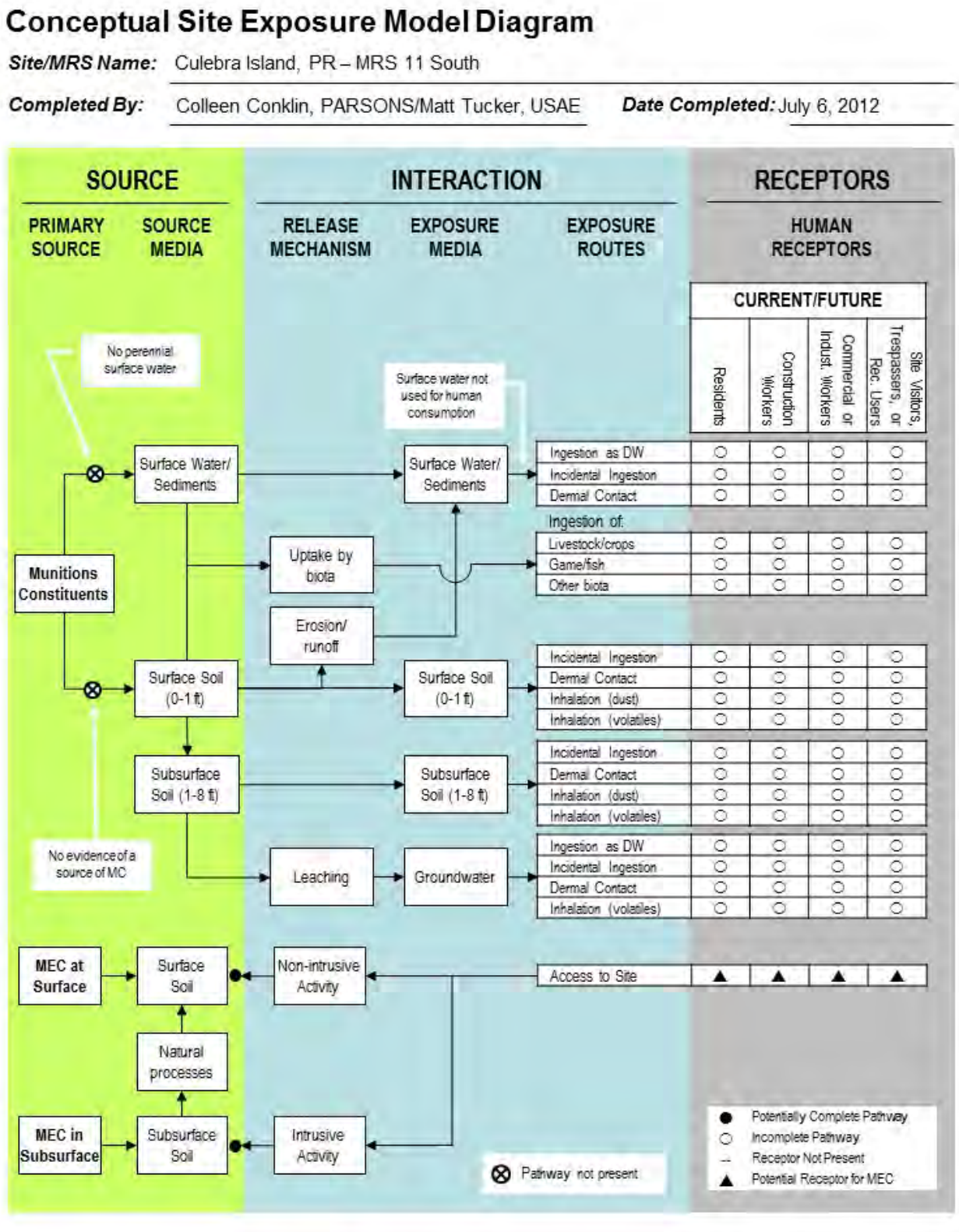

Figure 5-8: Revised CSM for MRS 11 South

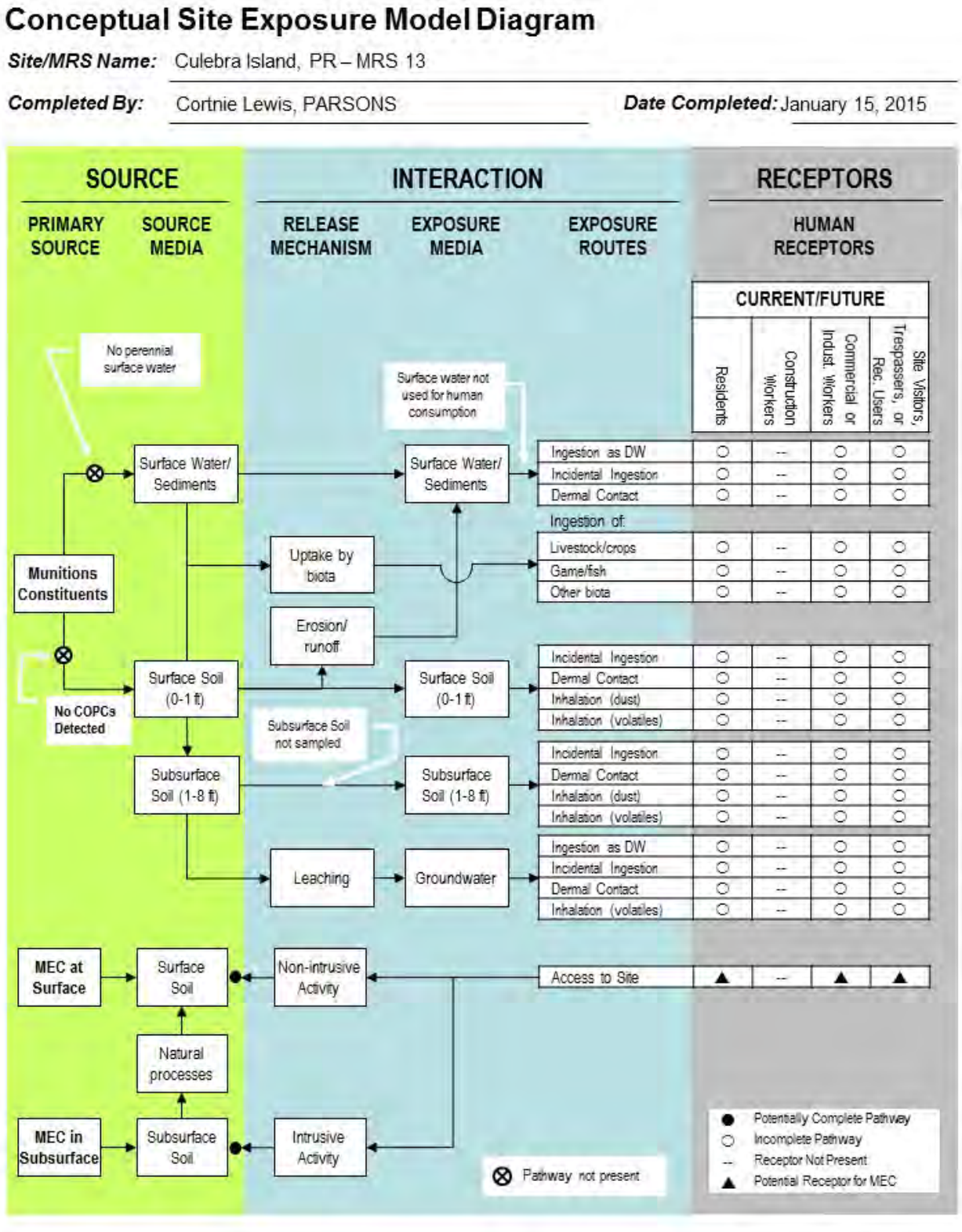

Figure 5-9: Revised CSM for MRS 13

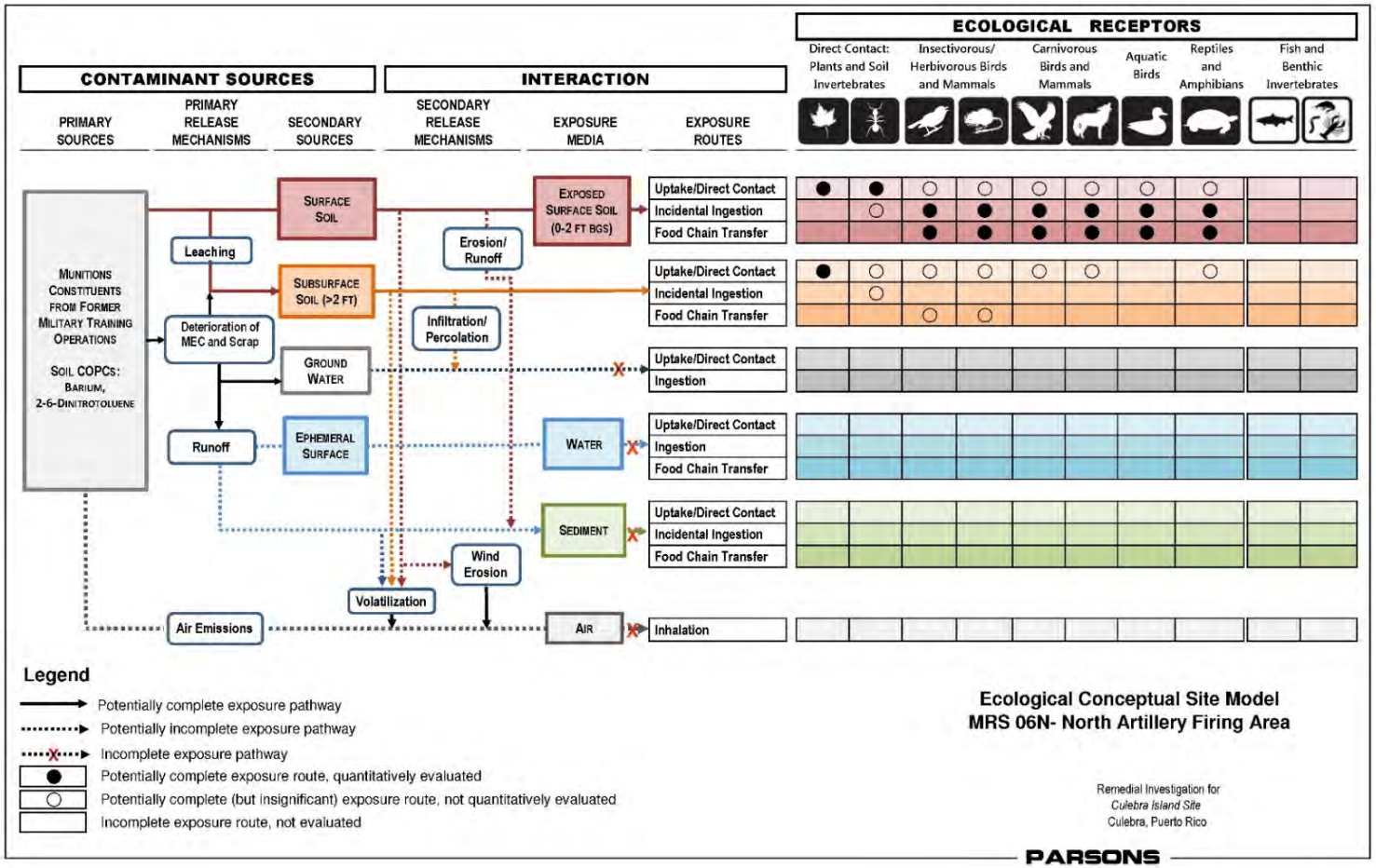

Figure 5-10: Revised ECSM for MRS 06 North

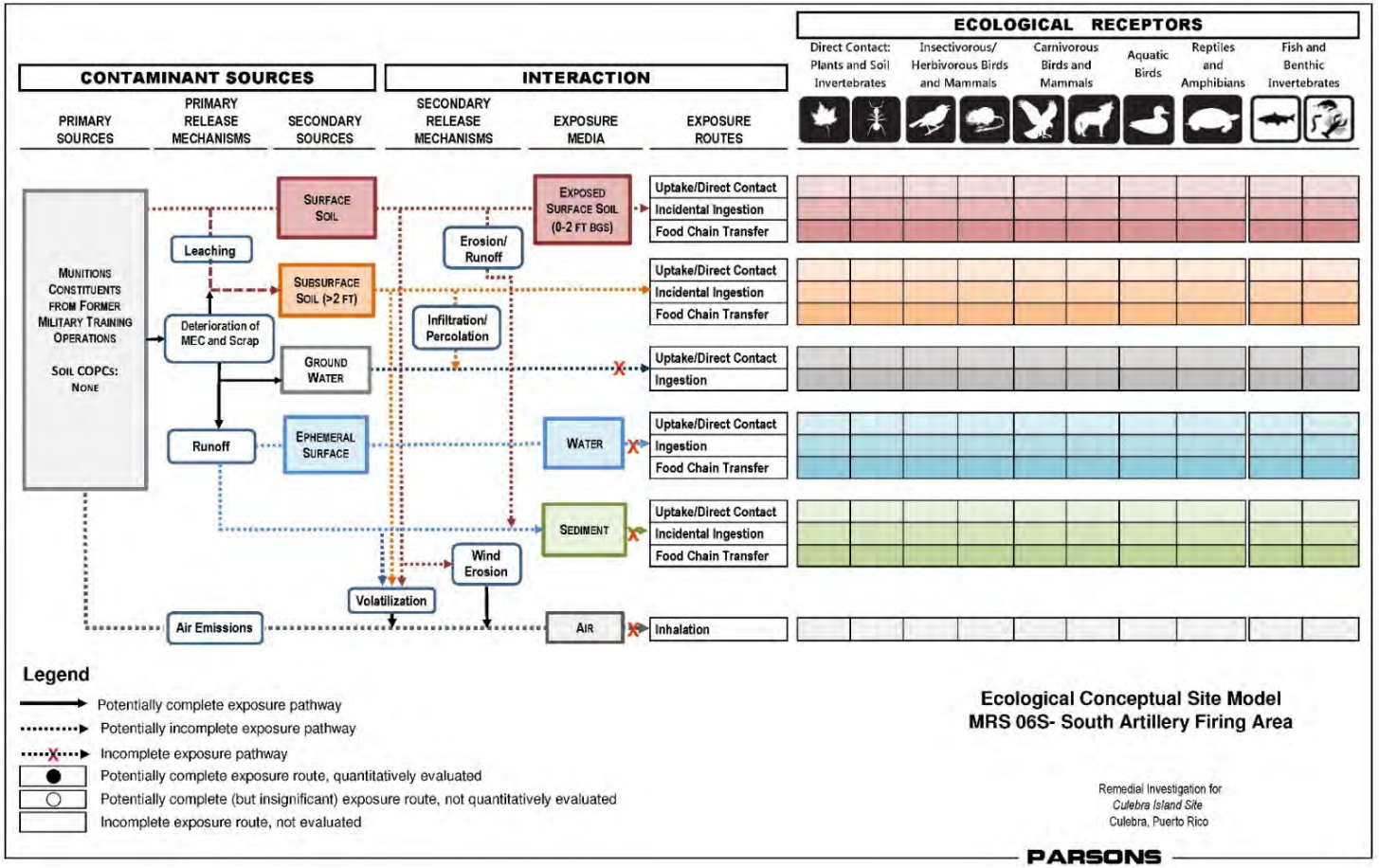

Figure 5-11: Revised ECSM for MRS 06 South

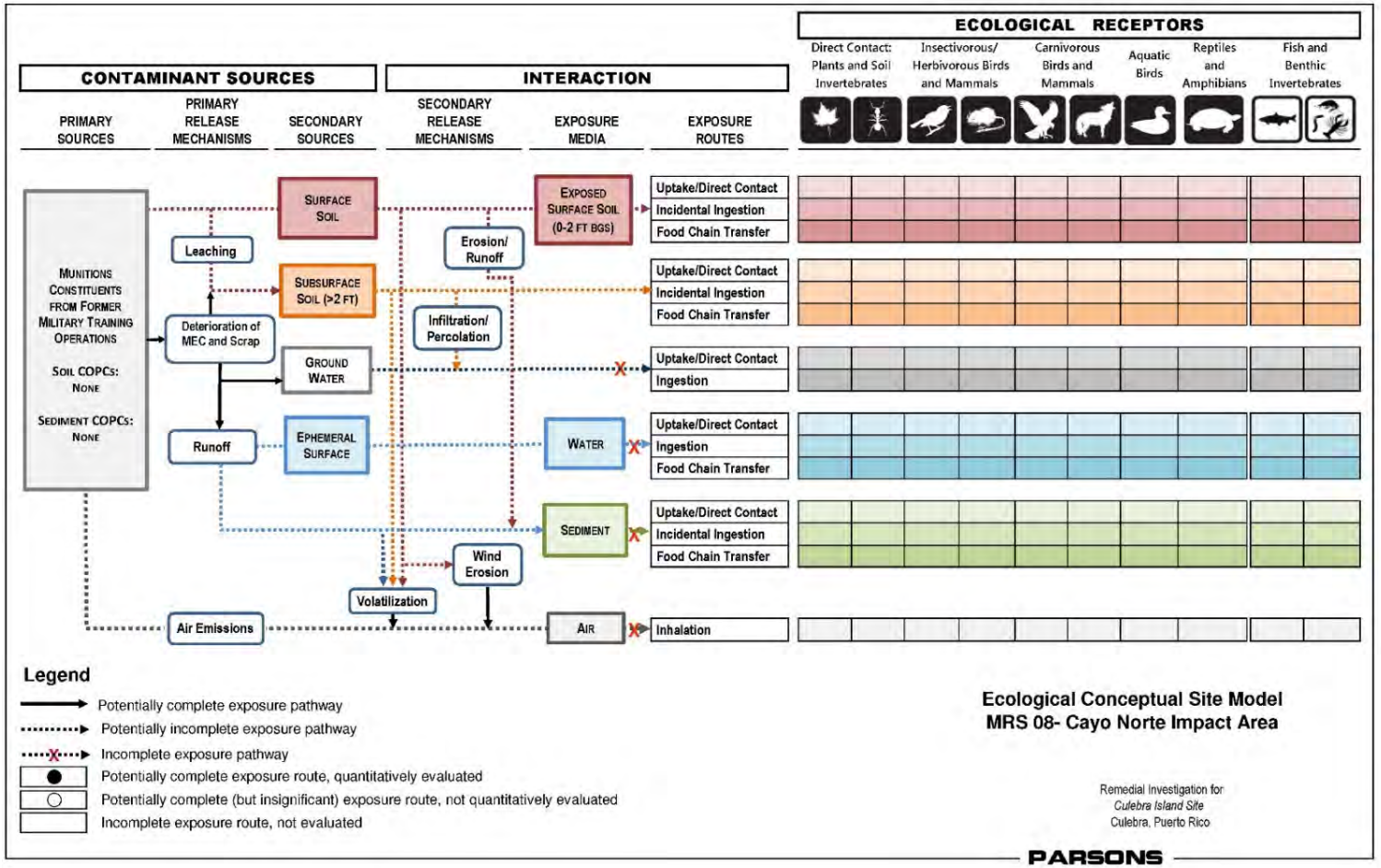

Figure 5-12: Revised ECSM for MRS 08

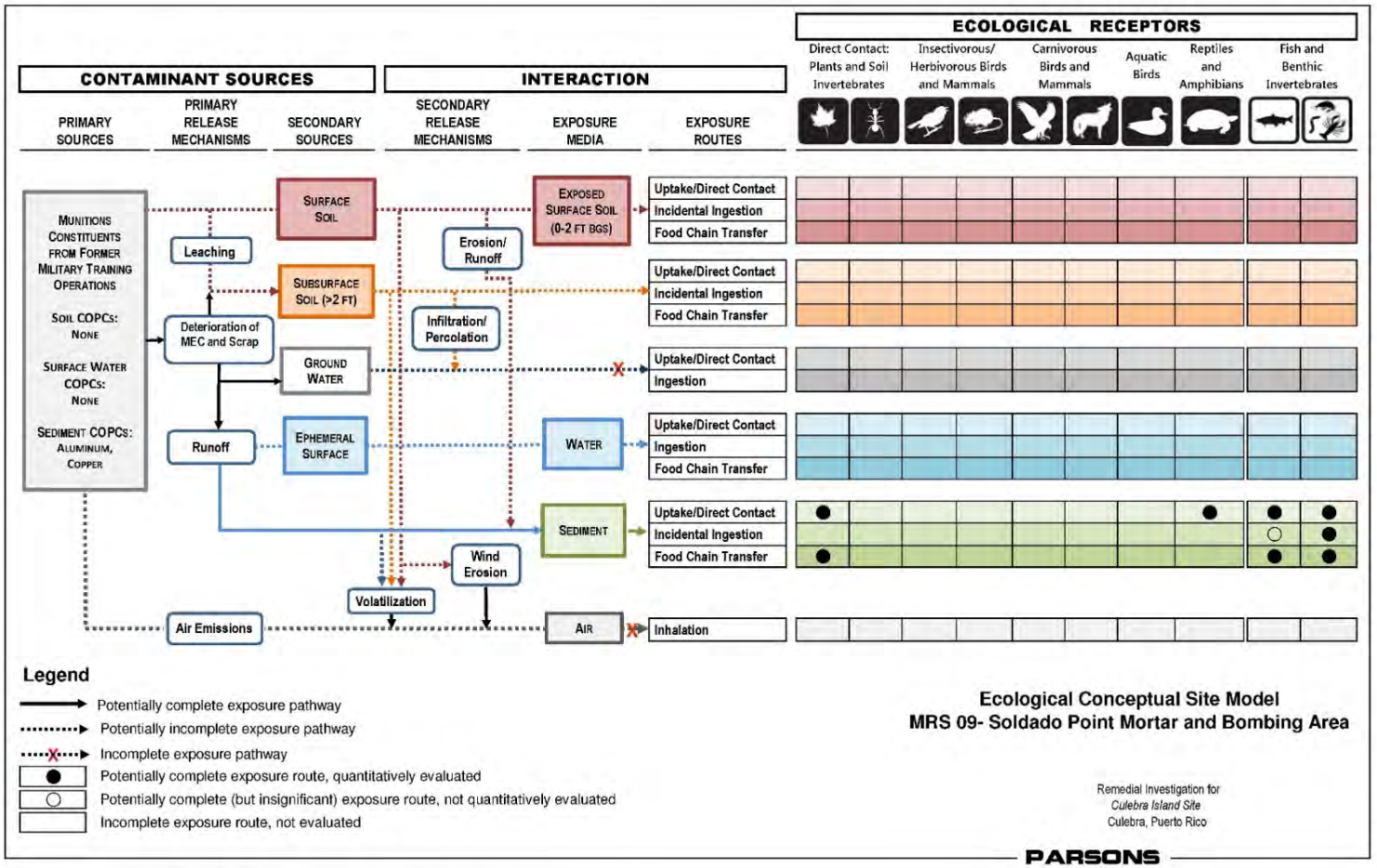

Figure 5-13: Revised ECSM for MRS 09

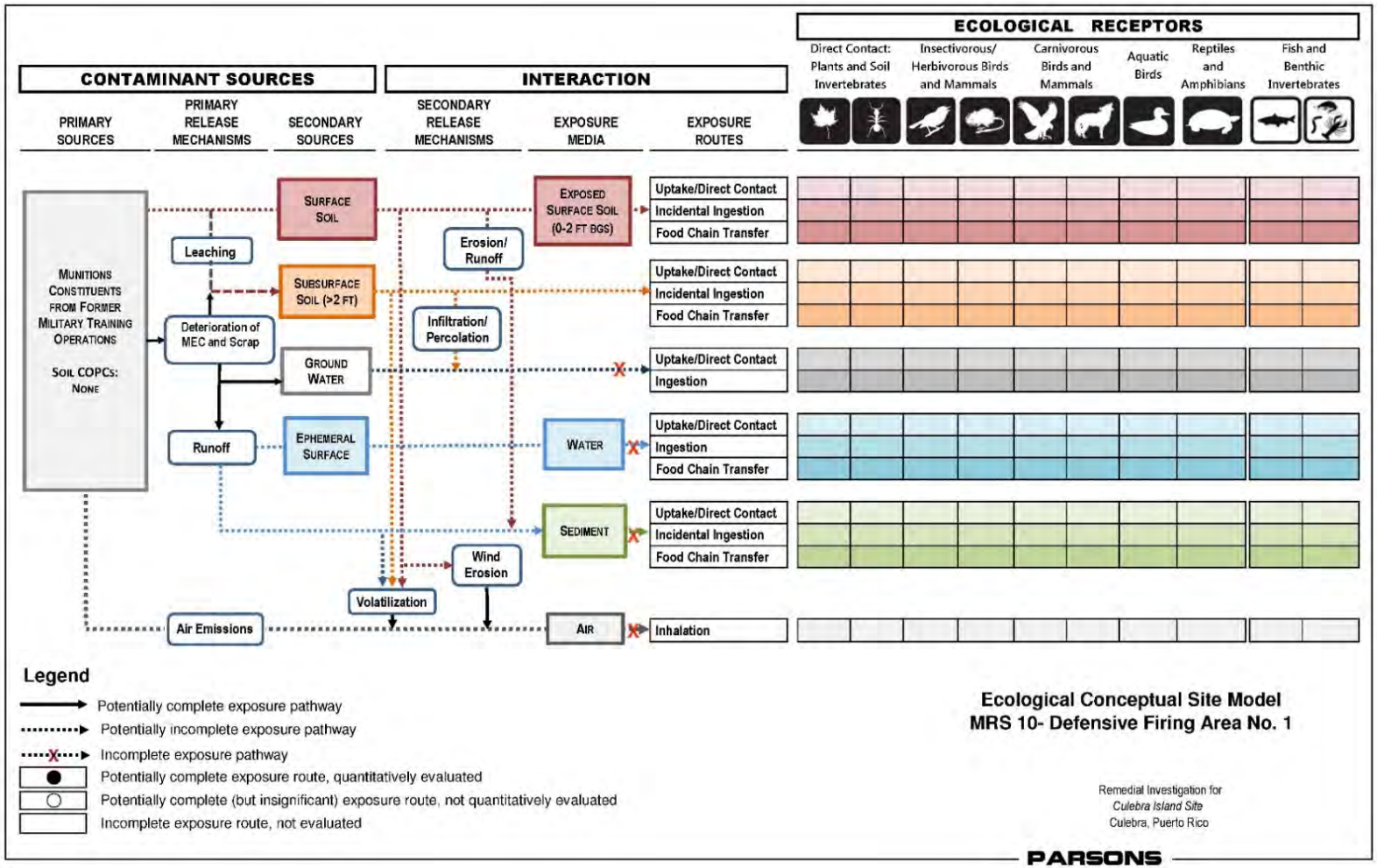

Figure 5-14: Revised ECSM for MRS 10

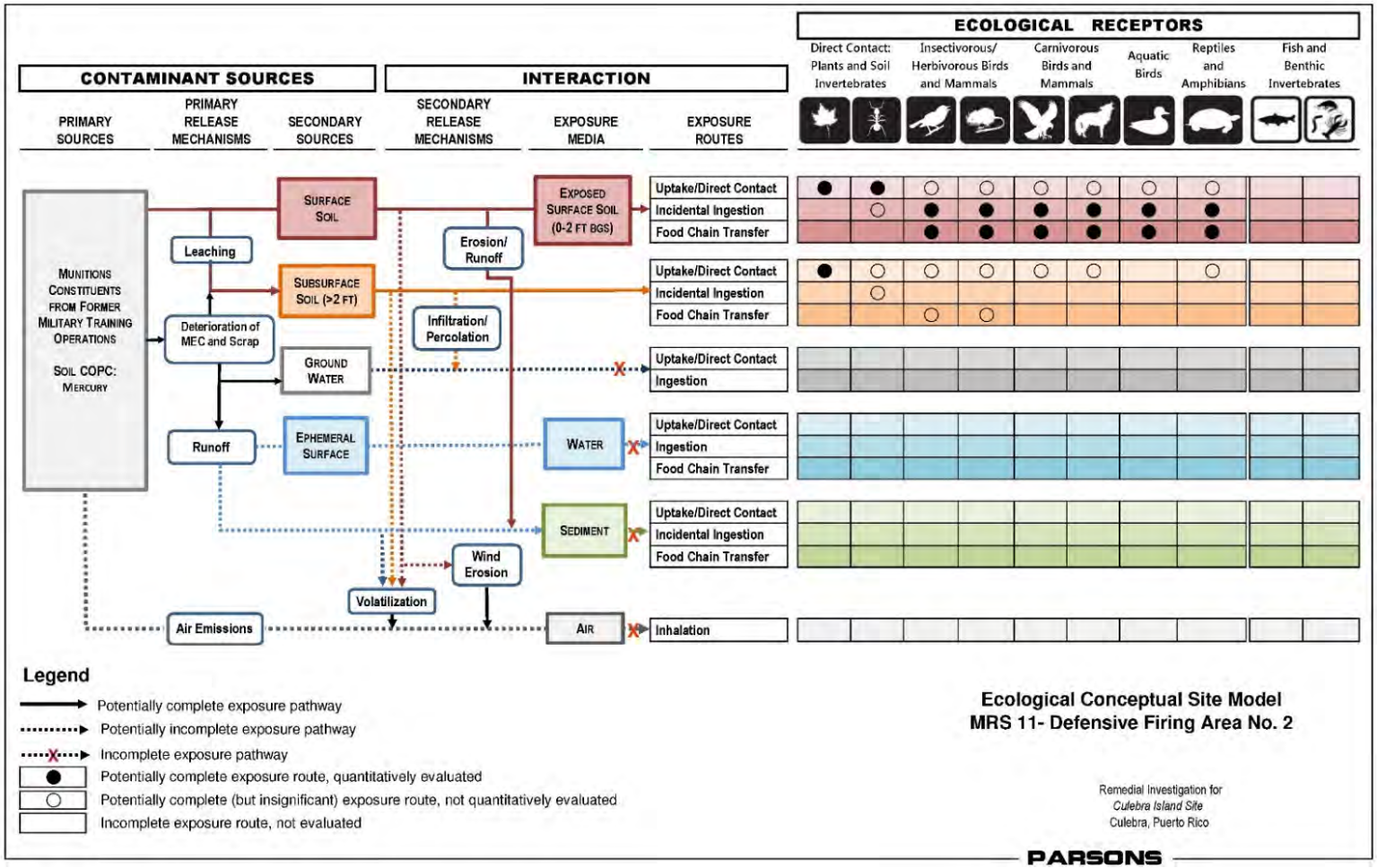

Figure 5-15: Revised ECSM for MRS 11

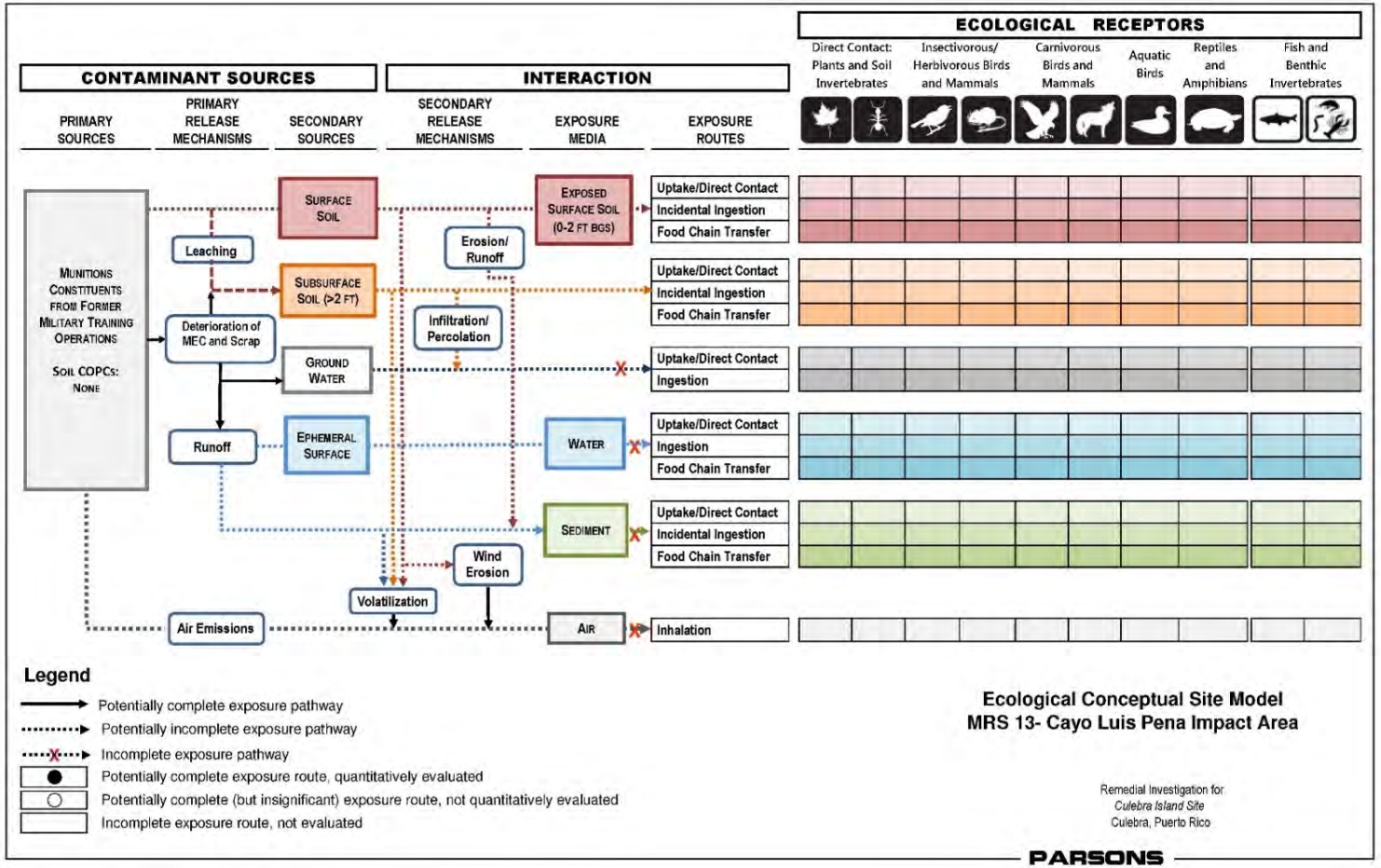

Figure 5-16: Revised ECSM for MRS 13

CHAPTER 6. CONTAMINANT FATE AND TRANSPORT FOR MEC AND MC

6.1 FATE AND TRANSPORT OF MEC

The primary MEC transport mechanisms identified at the Culebra Island MRSs include soil disturbance and erosion. Other human activities such as beach replenishment and relocation of MEC/MD items are possible transport mechanisms. Based on the current and anticipated future use of the MRS, intrusive activities and shoreline erosion (beach areas) are the most likely pathways for exposures to MEC within the Culebra Island MRSs.

6.2 FATE AND TRANSPORT OF MC

Many different environmental processes act upon MC which may influence or alter its availability to interact with receptors. These processes are fully reliant on the media in which the potential source (MEC or MD) exists and the exposure of MC to the processes. These environmental processes work through the different media: air, soil, surface water, groundwater, or biota. The following list contains short descriptions of these processes as described in Hewitt, et al. (2003):

- **Advection** – the passive movement of a solute with flowing water.
- **Dispersion** – the general term applied to the observed spreading of a solute plume and generally attributed to hydrodynamic dispersion and molecular diffusion.
- **Adsorption/desorption** – the process by which dissolved, chemical species accumulate (adsorption) at an interface or are released from the interface (desorption) into solution.
- **Diffusion** – the migration of solute molecules from regions of higher concentration to regions of lower concentration.
- **Biotic transformation** – the modification of a chemical substance in the environment by a biological mechanism.
- **Oxidation/reduction** – reactions in which electron(s) are transferred between reactants.
- **Covalent binding** – the formation of chemical bonds with specific functional groups in soil organic solids
- **Polymerization** – the process by which the molecules of a discrete compound combine to form larger molecules with a molecular weight greater than that of the original compound, resulting in a molecule with repeated structural units.
- **Photolysis** – the chemical alteration of a compound due to the direct or indirect effects of light energy.
- **Infiltration** – the process by which water enters the soil at the ground surface and moves into deeper horizons.
- **Evapotranspiration** – the collective processes of evaporation of water from water bodies, soil and plant surfaces, and the transport of water through plants to the atmosphere.
- **Plant root uptake** – the transport of chemicals into plants through the roots.

- **Sedimentation** – The removal from the water column of suspended particles by gravitational settling.

6.3 CONTAMINANT PERSISTENCE FOR MC

The MC discussed in this section are only those that upon completion of the screening level risk assessment warranted further consideration and consequently, have the potential to present an unacceptable risk to human health or the environment. For MRSs 06, 09, and 11, the only MC in soil that met this criterion are aluminum, barium, copper, mercury, and 2,6-Dinitrotoluene. For MRS 06S, 09, and 11N the MC in groundwater that met this criterion are copper and chromium.

6.3.1 Metals

Metals, although naturally occurring, can be a concern when casings, projectiles, fuzes, propellants, or other components of military munitions corrode or leach into the environment.

Chemical and physical properties affect the mobility of metals in soil and groundwater. A variety of reactions can occur that influence the speciation and transport of metal contaminants in soil and groundwater environments including acid/base, precipitation/dissolution, oxidation/reduction, sorption or ion exchange. The rate and extent of these reactions depends on factors such as pH, complexation with other dissolved constituents, sorption and ion exchange capacity of the geological materials, and organic matter content. Under relatively acidic conditions (pH ranges between 4.0 and 8.5), metal cations are mobile while anions tend to transform to oxide minerals. At high pH levels, cations adsorb into mineral surfaces and metal anions are mobilized. Other changes in soil environment conditions over time, such as the degradation of the organic waste matrix, oxidation-reduction potential, or soil solution composition, due to natural weathering processes, also may enhance the mobility of metals. The immobility of metals is primarily caused by reactions that cause metals to precipitate or chemical reactions that keep metals in a solid phase (Evanko and Dzombak, 1997).

To determine the potential existence of these MC within the sites investigated, environmental samples (soil, surface water, sediment) were collected and analyzed during the SI and RI field efforts.

6.3.2 Aluminum

Aluminum is an abundant natural element and the most common metal in the earth's crust. The aluminum content of soils is strongly correlated with its clay content and soil pH. Aluminum is released to the environment both by natural processes of soil weathering and anthropogenic sources such as mining and agriculture. Aluminum is not found as a free metal because of its reactivity, but occurs in the form of silicates, oxides, hydroxides, and as complexes with organic matter [Hazardous Substances Data Bank (HSDB), 2011]. Aluminum and its compounds appear to be poorly absorbed in humans. The mechanism of gastrointestinal absorption of aluminum has not yet been fully elucidated. The highest levels of aluminum may be found in the lungs, where it may be present as inhaled insoluble particles. The urine is the most important route of aluminum excretion.

At pH values above 5.0, aluminum ions become strongly bound as polymeric hydroxy cations at the surface of the silicate minerals. Exchangeable aluminum, as well as the aluminum concentration in the soil solution, is negligible. In the pH range 5 to 4.2, aluminum ions occupy

increasing fractions of exchangeable cations. Natural water systems acquire aluminum through weathering reactions, which involve the interaction of water and atmosphere with the earth's crust and subsequent leaching of aluminum compounds into water. Aluminum exists as trivalent aluminum in aqueous solution (HSDB, 2011).

Aluminum is used in munitions in incendiaries, composition explosives, propellants, pyrotechnics (powdered Al), and in rocket casings (alloys).

6.3.3 Barium

Barium occurs naturally in the earth's crust and is present largely as compounds with another element. Barium sulfate (barite) and barium carbonate (witherite) are two very insoluble naturally occurring minerals, which are commonly found as underground ore deposits. Barium and its compounds are also found naturally in food and drinking water. The types of barium compounds found in drinking water vary, as some compounds are not easily soluble with water. Those compounds which may be found in water are usually of the type that are not commonly found in nature and are most likely present due to localized anthropogenic sources. Barium's persistence is determined by the form (compound) in which it is released. Non-soluble forms of barium (e.g., barium sulfate) have the potential of persisting in the environment for a significant length of time, and those compounds which have greater water solubility tend to have a shorter life, but can eventually combine with sulfate or carbonate to form a more persistent compound. The sulfate and carbonate compounds have a higher partition to organic (soil) matter (ATSDR, 2009).

Barium has few industrial applications. Soluble barium compounds are poisonous due to the release of the soluble barium ion and have been used in rodenticides. Barium sulfate, because of its high density, is used in the petroleum industry as a weighting agent in drilling mud and it is also used as filler in rubber. Other barium compounds have niche applications including barium oxide, which is used as a coating for the electrodes in fluorescent lamps; barium carbonate, which is used in glassmaking; and barium nitrate, which is used to create green colors in fireworks.

Barium compounds (barium nitrate, barium stearate, and barium chromate) are used in propellant, energetic, and pyrotechnics (PEP) of military munitions (GAIA Corporation, 2002). Other non-munitions sources of barium at Culebra could be attributed to the natural geology of the site.

6.3.4 Chromium

Anthropogenic sources include combustion of fossil fuels, pigments, metal alloys, glass coloring, steel and welding materials, textile industry, photography, fuel additives, magnetic tapes, industrial water treatment, paper mills, and fertilizers. Additionally, chromium is found naturally in rocks, ores, minerals, volcanic dust, and gases from the earth's crust. Under normal conditions, chromium is dispersed throughout the environment primarily as a result of anthropogenic activity. The concentration of chromium varies widely in soil. For example, in a study within the conterminous United States, chromium concentrations in soil ranged from 70 parts per million (ppm) to 700 ppm (USGS, 1984).

Chromium occurs in two major forms; trivalent or chromium (III) and hexavalent or chromium (VI). Chromium (III) is considered an essential nutrient for humans. Hexavalent chromium is

more toxic. Chromium is primarily present in soil as insoluble oxide (Agency for Toxic Substances and Disease Registry [ATSDR], 2008).

Chromium (VI) is eventually reduced to chromium (III) by the organic material present in surface water and generally forms stable complexes with organic matter. Therefore, based on the potential source of chromium (i.e., munitions) and absence of surface water bodies, chromium is expected to be present in soil at Culebra Island as chromium (III). To be conservative, however, hexavalent and trivalent chromium were both further evaluated in the risk assessment.

Chromium used in munitions is a component of armor piercing bullets, pyrotechnics, and present in some steel alloys of casings.

6.3.5 Copper

Copper occurs naturally in rock, soil, water, and sediment. Copper occurs in numerous minerals such as cuprite, tenorite, malachite, and azurite. It is an essential element for all known living organisms including humans and other animals at low levels of intake, with dietary ingestion providing the primary source of the necessary copper (HSDB, 2001). Copper is primarily used in the manufacture of wire, sheet metal, pipe, in agriculture to treat plant diseases, for water treatment, and as preservatives for wood, leather, and fabrics.

When copper is released into soil, it can become strongly attached to the organic material and other components (e.g., clay, sand, etc.) in the top layers of soil and may not move very far when it is released. Hydrolysis and precipitation reactions dominate the chemistry of copper compounds in most natural aqueous systems. Soluble copper compounds sorb strongly to suspended particles. The presence of complexing organic ligands can stabilize dissolved copper compounds in fresh water systems and prevent copper sorption onto solids. Most insoluble and soluble copper compounds are associated with solids, have low mobility in soil, and are not expected to volatilize from water or moist soil surfaces. There is no evidence that supports the existence of biotransformation processes for copper compounds which would have a significant bearing on the fate of copper in aquatic environments (HSDB, 2001).

Copper is used extensively in military munitions in alloys of casings, solid munition components, paints, and coatings. Copper is also a constituent of the jet perforators used for the demolition of munitions.

6.3.6 Mercury

Mercury can be emitted to the atmosphere as a gas (elemental and oxidized chemical forms) or a particulate (oxidized forms), and subsequently return to the earth in the form of dry or wet deposition. The residence time of mercury emissions in the atmosphere is influenced by state (e.g., whether it is in gas or particulate form) and solubility, with vapor forms of elemental mercury having the longest residence times (NESCAUM et al., 1998). Over 95% of the atmospheric mercury is in the elemental form as mercury vapor (RTI, 1999). Elemental mercury vapor is not thought to be susceptible to any major direct deposition processes due to its relatively high vapor pressure and low water solubility. However, ozone promotes the oxidation of elemental mercury to the more-soluble divalent form, which is then subject to dissolution into precipitation and subsequent wet deposition or binding to particles which are then subject to dry and wet deposition (USEPA, 1997). Methylmercury is also present in wet deposition, although at much lower concentrations than divalent mercury. Atmospheric deposition as a source of

methylmercury has been found to decrease with distance from areas of ocean upwelling and industrial sources (South Florida Water Management District, 1999).

If deposited in a soil environment, divalent forms of mercury complex with organic matter and mineral materials to form inorganic compounds [e.g., $HgCl_2$ and $Hg(OH)_2$] and complexes of inorganic divalent mercury and organic compounds. While inorganic mercury compounds are quite soluble, they form complexes with soil organic matter and, to a lesser extent, mineral colloids. These complexes greatly limit the mobility of the inorganic mercury compounds. As a result, much of the soil mercury is bound to organic materials and is then subject to removal by erosion. To a minor extent, the divalent mercury can be absorbed onto dissolvable organic ligands and other forms of dissolved organic carbon and thereby be removed via runoff. Leaching is a relatively insignificant transport process (ATSDR, 1999). Microbial processes acting on divalent mercury compounds can cause small amounts of methylmercury to form in surface soil. Methylmercury typically accounts for only 1 to 3% of the total mercury in surface soils (the percentage can exceed 3% in soils with high organic content under slightly acidic conditions). The presence of humic substances and light can also reduce divalent mercury in soil to elemental mercury, which is then subject to volatilization (USEPA, 1997).

Mercury is used in munitions as a primary explosive in the form of mercury fulminate.

6.3.7 Fate and Transport Processes for Explosives

2,6-Dinitrotoluene was identified as a COPC in the surface soil at MRS 06 North. Explosives are generally classified as "primary" or "secondary." In munitions, secondary explosives are used in much greater quantities than primary explosives, and are known to be more prevalent at military installations (USEPA, 2006). Secondary explosives can be classified according to their chemical structure as nitroaromatics such as TNT and nitramines such as RDX. 2,6 Dinitrotoluene is the result of incomplete nitration products of TNT synthesis and a component of certain propellants and impurities in TNT manufacturing.

6.4 SUMMARY

As stated in Chapter 5, four metals and one explosive compound were detected in soil and two metals in groundwater at concentrations above screening levels and are associated with munitions that were used during military operations at Culebra. A representation of environmental conditions for the Culebra Island Site is discussed below.

The six MRSs that were evaluated at part of this RI/FS Risk Assessment are at noncontiguous locations within the Culebra Island Site; however, these sites contain similar types of soils. The soils that make up these sites are DeE2, DrF, Rs, Ts, and AmC2. These soils tend to consist of silts and clays, which are shallow, and become more organic near the beaches.

Average rainfall in Culebra is approximately 40 inches, with the heaviest rain in September, October, and November. The months of August through November are considered the wet season, and the driest months are January through April.

Constituents released as part of the destruction of UXO by detonation present the possibility of a future contaminant release into the environment, which could potentially affect humans or ecological receptors coming into contact with the contaminant. Risks associated with these MC and the pathways present are further evaluated in Chapter 7.

CHAPTER 7. BASELINE RISK ASSESSMENT FOR MC AND HAZARD ASSESSMENT FOR MEC

7.1 INTRODUCTION

The need for remedial actions to reduce risks to human health or the environment must be demonstrated through the use of either quantitative or qualitative risk assessments. A baseline risk assessment (RA) evaluates potential current and future adverse health effects caused by hazards (MEC) or hazardous substance (MC) releases from a site in the absence of any actions to control or mitigate these releases. In addition, the risk assessment evaluates the magnitude of the risk at the site and the primary causes of that risk. The baseline risk assessment does not include releases associated with actions taken to mitigate imminent hazards (e.g., detonations to remove MEC). The results of the risk assessment aid in the development, evaluation, and selection of appropriate response alternatives.

Baseline risk assessments are site-specific evaluations and may vary in both detail and extent to which qualitative and quantitative inputs are used. Generally, risk assessments follow a phased approach, starting with generic assumptions and moving toward a more complex site-specific evaluation as necessary. The characteristics of the risk assessment depend on the complexity and particular circumstances of the site as well as the availability of ARARs and other guidance. The risk assessments also consider the potential risks associated with current land use and activities, as well as reasonably anticipated future land use.

7.2 Potential for Adverse Effects from MC

The MC baseline risk assessment was conducted in accordance with *USEPA Risk Assessment Guidance for Superfund (RAGS),* and USACE EM 200-1-4 *Risk Assessment Handbook*. The MC baseline risk assessment described in the following sections evaluates the potential for adverse effects on both human and ecological receptors associated with each exposure pathway. An exposure pathway is considered complete if there is a clear potential for human and/or ecological receptors to be exposed to a chemical hazard. The MC baseline risk assessment first identifies those constituents that require further evaluation in a SLRA. The MC baseline risk assessment then assesses the potential significance of complete exposure pathways (that is, whether there is an unacceptable risk). The objectives of this MC baseline risk assessment are to:

- Determine whether an unacceptable risk is present
- Provide a quantitative baseline human health risk assessment and an ecological risk assessment if unacceptable risks have been identified in baseline risk assessment screening steps.

The sections below discuss the protocols used in the baseline risk assessment. COPCs are site-related chemicals that have been retained for analysis in the baseline risk assessment. Chemicals of concern are those chemicals identified for consideration in a FS based on results of the baseline risk assessment.

7.2.1 Phased Risk Assessment Approach

The results of the prior investigations conducted for the Culebra Island MRSs were used to develop a sampling strategy for the RI. An initial characterization of the analytical data determined whether there was evidence of a release of contaminants at the MRSs. At the Culebra Island MRSs, one explosive compound (2,6-Dinitrotoluene) was detected in one surface soil sample at a concentration greater than the selected PSV. For metals, a concentration greater than the PSV indicates a potential release has occurred. If the maximum detected concentration of a metal does not exceed its PSV, then there is no evidence of a release and further risk evaluation is not conducted for the analyte.

If evaluation of the data indicates that a release has likely occurred, a baseline risk assessment is conducted in a stepwise manner, moving from a relatively simple SLRA to a more complex deterministic risk assessment, as needed.

If a release was determined, the potential exposure pathways and potential receptors identified in the CSM were evaluated. If a release was indicated, and complete exposure pathways were identified, then representative concentrations of each COPC found above PSV (these analytes are now considered COPCs), were used to determine the potential for a human health or ecological risk.

7.2.2 Potential Exposure Pathways for Human and Ecological Receptors

The Culebra Island FUDS consists of 8,430 acres of land primarily privately owned with portions managed by the USFWS and PRDNER. All areas within the Culebra Island FUDS have unrestricted public access; however, vegetation and terrain are natural barriers, limiting access to portions of the MRSs. Much of the island is accessed regularly by the 2,000-plus local residents and many yearly visitors. Potential human receptors for these sites include residents, recreational users, site visitors, construction workers, and commercial/industrial workers. Ecological receptors can also come into contact with MC. Although a biological survey has not been conducted within these MRSs, the area is likely to contain the typical fauna and flora associated with the islands of Puerto Rico (Section 2), including sensitive, threatened, and endangered species. Ecological receptors including sensitive and endangered species are considered present within all of these MRSs.

Potential exposure pathways to both human and ecological receptors are presented below. The MC CSM identifies affected media, transport mechanisms, exposure routes, and potential receptors; CSMs developed for each Culebra Island MRS are included in Chapter 5.

7.2.2.1 Surface Soil

Direct release of MC from munitions activities would have been to surface soil. Potential exposure to MC contamination in surface soil typically occurs through the following pathways:

- Incidental ingestion of soil
- Dermal contact with soil
- Inhalation of re-suspended particulate matter from soil.

Potential human receptors which could interact with MC through the pathways mentioned above include residents, recreational users, site visitors, construction workers, and commercial/industrial workers.

Potential ecological receptors in these areas would potentially be exposed to MC through ingestion, dermal contact, and inhalation.

Wildlife and game species (i.e., feral hogs and deer) are present at the site, and have the potential of being exposed to MC while grazing or digging in the area.

7.2.2.2 Surface Water and Sediment

Due to runoff from the surrounding areas and the presence of aquatic habitats within MRS 09, surface water and sediment are present within this MRS. Potential exposure to MC contamination in surface water and sediment could occur through the following pathways:

- Incidental ingestion of surface water or sediment
- Dermal contact with surface water or sediment.

Similar to the soil pathways, potential human receptors that may encounter surface water and sediment through the course of their activities include residents, recreational users (e.g., hunters), visitors, construction workers, and commercial/ industrial workers.

Potential ecological receptors that would be exposed to surface water or sediment exist at MRS 09. Receptors in these areas would potentially be affected through the ingestion and dermal contact pathways.

7.2.2.3 Groundwater

MC present in soil has the potential to leach to a shallow aquifer. Potential exposure to MC in groundwater could occur through:

- Incidental ingestion of groundwater
- Dermal contact with groundwater.
- Ingestion of groundwater as drinking water.

Potential human receptors include current and future residents and on-site workers who, during their activities on site, may encounter groundwater through the course of their activities. Additionally, construction workers could encounter groundwater during excavation activities. No potable wells are known to exist within the site that could expose receptors to the ingestion pathway. No restriction currently exists on installation of future wells, but all wells must receive an approved permit for installation.

Potential ecological receptors during their activities are not expected to access subsurface groundwater and are therefore are unlikely to encounter groundwater on-site.

No data is available to accurately map groundwater flow on Culebra. Given the fractured nature of the underlying volcanic and plutonic rock, confined aquifers are not likely present. It can reasonably be assumed the groundwater will flow from areas with higher potentiometric surfaces at higher elevations towards lower elevations, in the bays and ocean, taking the shortest path. The shortest path of flow would generally be perpendicular to topographic contours (Figure 1-2).

Travel will be within fractures of the volcanic bedrock and within the patches of alluvial deposits. Travel within the fractures could follow a slightly diverted path, but general flow will be toward decreasing elevation contours to the nearest water body.

7.3 MC Risk Evaluation

7.3.1 Screening Level Risk Assessment

Direct contact of residential receptors to soil through incidental ingestion, dermal contact, and inhalation of soil particulates and volatiles was used to develop conservative screening criteria. The maximum detected concentrations of COPCs are compared to the residential soil screening levels to determine the potential for a human health risk. If the maximum detected concentration of the COPC does not exceed the screening value, it is assumed that there is no unacceptable risk and the risk assessment process is considered complete. Maximum detected concentrations of COPCs less than screening levels are not expected to pose an unacceptable risk to human receptors, including residential receptors. Because the screening levels are based on conservative exposure assumptions, even if a detected chemical is found at concentrations greater than the screening value, it does not necessarily indicate that an unacceptable risk is present.

To evaluate human health risk due to exposure to soil and groundwater, the maximum detected concentration of each COPC in each MRS is compared to the appropriate human health screening value. Cumulative carcinogenic risks and noncarcinogenic hazard quotients (HQ) will be calculated and evaluated for each COPC listed for human exposure to groundwater.

The potential for noncarcinogenic effects is evaluated by comparing an exposure level or intake derived for a similar exposure period. The ratio of the exposure concentration to the noncarcinogenic toxicity value is the HQ. In other words, HQ equals the intake divided by the corresponding reference value: A HI in excess of one (1) indicates the potential for noncarcinogenic health effects.

Carcinogenic risk is expressed as an increased probability of developing cancer as a result of lifetime exposure to a COPC. For simultaneous exposure to several carcinogens, USEPA assumes that risks are additive: USEPA's (1991) target carcinogenic risk management range for environmental remediation sites is one-in-one million (1E-06) to one-in-ten thousand (1E-04).

To evaluate ecological risk in soil for the site, the maximum detected concentration of each COPC is evaluated using the appropriate ecological screening value. This comparison results in the calculation of a HQ for each analyte. A HQ is calculated by determining the ratio of the representative concentration to the screening value. Calculated HQ values are rounded to the nearest whole number. If the HQ is equal to or less than one (1), the potential for ecological risk is considered to be negligible. If the HQ is greater than one (1), then unacceptable ecological risk should not be ruled out based on the screening comparison alone. An HQ greater than one (1) is further reviewed to evaluate the significance of the exceedance.

7.3.2 Risk Evaluation

A risk evaluation was conducted for those COPCs identified in the characterization step. The MC baseline risk assessment evaluated the potential for adverse effects on both human and

ecological receptors associated with each exposure pathway. In the following sections, COPCs that were identified for each MRS are evaluated in the following order:

- Site-by-site, medium-specific SLRAs were conducted.
- COPC concentrations for each medium at a site were evaluated first using human health screening values, then using ecological screening values (ESVs).
- Each COPC identified in the SLRA as exceeding human health screening values or ESVs was then evaluated in more detail.
- As appropriate, past and present land uses were considered to determine if alternate screening values were applicable.
- The final step in the baseline risk assessment included quantitative risk calculations for those COPCs that were found to exceed relevant human health and/or ESVs and be attributable to former munitions use at the site.

7.3.3 MRS 06 North

Based on the soil source evaluation in Subsection 5.4.1.1, one metal (barium) was identified as a COPC at MRS 06N.

Based on the soil source evaluation in Subsection 5.4.1.1, the maximum detected concentration of barium, was greater than its PSV. Soil sample (PR-1014-S-084) had a concentration (750 mg/kg) that exceeded the PSV (710 mg/kg). Thirteen additional samples were collected surrounding sample PR-1014-S-084 and analyzed for barium; of these 13 samples, five had concentrations that exceeded the PSV for barium.

The maximum detected concentration of barium (1,100 mg/kg) did not exceed the human screening value (1,500 mg/kg); therefore, no risk to human health is expected from exposure to soil at MRS 06N. The maximum detected concentration of barium in soil at MRS 06N was 1,100 mg/kg; this concentration exceeds the ESV for invertebrate receptors (EcoSSL = 330 mg/kg) resulting in a HQ of 3; the maximum concentration of barium does not exceed the ESV for mammals (EcoSSL = 2,000 mg/kg) and there is no published EcoSSL for plants or avian receptors. The maximum detected concentration of barium exceeds the BTV (710 mg/kg) by a factor of 1.5.

Soil sample PR-1014-S084 was collected at Grid 6-17; during the intrusive investigation phase of Grid 6-17, one item was classified as being MD. Although this piece was identified as a piece of rotating band, historical use of this portion of MRS 06 does not indicate that Grid 6-17 was located within an impact area. According to the ASR and ASR Supplement, there were no indications that firing points or military structures were located in the vicinity of Grid 6-17. Given that this item was the only MD recovered in Grid 6-17 and there is no documented military use at this grid, it is unlikely that the recovered MD indicates that Grid 6-17 was within an impact area. The 75mm M48 projectiles (the munitions with documented use at MRS 06), were not fired at the MRS, they were fired toward off island targets. There is no indication that munition related contamination exists in this area. The Stokes Mortar is the only documented munition that contained small amounts of barium in the form of barium nitrate and was used against floating targets in Mosquito Bay. The firing points were identified as near Mosquito bay. There is no documented use of the Stokes Mortar or indications of its use near Grid 6-17. In addition, it should be noted that barium in the form of barium nitrate and to some degree barium

chromate is used in munitions as a primary explosive (primers and fuzes) in a small amount (usually measured in grams). Based on the small quantities of MD found indicating no concentrated munitions use, it is unlikely that barium exceedances are indicative of DoD use but may be the result of barium naturally being present in the soil. Barium concentrations have been found naturally occurring in other parts of the island higher than the maximum detected barium concentration at the location in question. If munitions were the source other explosives related exceedances would have been expected to be present (i.e., TNT, lead, etc.).

Based on the groundwater source evaluation, no analytes were detected exceeding their respective PSVs. Therefore, there is no evidence of a release of MC to groundwater at MRS 06 North and the site will not be further evaluated in the risk assessment.

7.3.4 MRS 06 South

Based on the soil source evaluation in Subsection 5.4.1.2, explosives were not detected in any soil samples and the maximum detected concentration of metals did not exceed their PSVs; therefore, soil in MRS 06S was not evaluated further in this risk assessment.

Based on the groundwater source evaluation, the maximum concentrations of one metal, chromium in the form of chromium (VI), exceeded its human health screening value and was evaluated in the risk assessment as a COPC. The exposure point concentration of chromium (VI) for comparison was determined per the rationale described in Section 4.2.8.4. Chromium was evaluated for both noncarcinogenic and carcinogenic effects.

Multiple receptors were identified in the CSM as having potentially complete groundwater exposure pathways at MRS 06 South. These receptors include: current/future residents, construction/excavation workers, and commercial/industrial workers. Risk results for each receptor are presented below. Tables with risk calculations are located in Appendix P.

Current / Future Resident

As presented in Table P.2, evaluation of ingestion of groundwater as drinking water results in a cancer risk of 1E-06 and a HQ of 0.002, indicating no expected unacceptable risk.

As presented in Table P3, evaluation of dermal exposure to groundwater results in a cancer risk of 6E-07 and a HQ of 0.001, indicating no expected unacceptable risk.

Construction / Excavation Worker

Construction/excavation worker pathways include incidental ingestion and dermal exposure to groundwater.

As presented in Table P.4, the evaluation of incidental ingestion of groundwater results in a cancer risk of 3E-10 and a HQ of 0.0001, indicating no expected unacceptable risk.

As presented in Table P.4, the evaluation of dermal exposure to groundwater results in a cancer risk of 9E-10 and a HQ of 0.00004, indicating no expected unacceptable risk.

Commercial / Industrial Worker

Commercial/ industrial worker pathways included: incidental ingestion of groundwater and dermal exposure to groundwater.

As presented in Table P.6, the evaluation of incidental ingestion of groundwater results in a cancer risk of 8E-08 and a HQ of 0.0001, indicating no expected unacceptable risk.

As presented in Table P.6, the evaluation of dermal exposure to groundwater resulted in a cancer risk of 7E-07 and a HQ of 0.001, indicating no expected unacceptable risk.

7.3.5 MRS 08

The 2007 SI results indicated that the concentration of zinc in soil exceeded its ecological screening value used in that report, generating an HQ of 1.8. However, the maximum detected concentration for zinc did not exceed the selected PSV used in this RI. Based on the soil source evaluation, explosives were not detected in any soil samples and the maximum detected concentration of metals did not exceed their PSVs; therefore, MRS 08 was not retained for further consideration in this risk assessment.

Based on the sediment source evaluation, the sediment/surface water exposure pathway is incomplete and is not considered further in this risk assessment.

Based on the groundwater source evaluation, the groundwater exposure pathway is incomplete for MRS 08 and will not be further evaluated in the risk assessment.

7.3.6 MRS 09

The 2007 SI results indicated that chromium exceeded its ecological screening value used in that report, generating an HQ of 48. However, when compared to the PSVs used in this risk assessment, chromium did not exceed the selected value. Based on the soil source evaluation, explosives were not detected in any soil samples and the maximum detected concentration of metals did not exceed their PSVs; therefore, the surface soil at MRS 09 was not retained for further consideration in this risk assessment.

Based on the surface water source evaluation, explosives were not detected in any surface water samples and the maximum detected concentration of metals did not exceed their PSVs. Therefore, the surface water at MRS 09 was not retained for further consideration in this RA.

Based on the sediment source evaluation, the maximum detected concentration of two metals, aluminum and copper, were greater than their human health screening values and sediment at this MRS was retained for further evaluation. For all three sediment samples collected at MRS 09 (PR-1012-SD-035, PR-022517-SD-036-RE, and PR-1012-SD-037), the concentration of aluminum was greater than the human health screening value; the concentration of copper was greater than its human health screening value in only one sample.

For sediment sample PR-1012-SD-035, the maximum detected concentration of aluminum (68,000 mg/kg) exceeded both the selected human health screening value (7,700 mg/kg) and the RI background value used for aluminum in sediment (57,000 mg/kg). However, the selected human health screening value was determined by dividing the USEPA RSL by 10 to reflect a HQ of 0.1 to account for potential cumulative effects. The maximum detected concentration of aluminum (68,000 mg/kg) does not exceed the unadjusted USEPA RSL (77,000 mg/kg). Sample PR-1012-SD-035 was the only sediment sample to exceed both the human health and background screening values. The concentration in sample PR-1012-SD-037 (44,000 mg/kg) collected on the same side of the lagoon as sample PR-1012-SD-035, did not exceed the background concentration. The concentration in sample PR-022517-SD-036-RE collected from

across the lagoon did not exceed the background concentration. Additionally, there were no exceedances of aluminum in the surface water samples collected from the lagoon.

Also in sample PR-1012-SD-035, the maximum detected concentration of copper (390 mg/kg) exceeded the selected human health screening value (310 mg/kg). The RI background value used for comparison for copper in sediment is also established to be 310 mg/kg. However, the selected human health screening value for copper was also determined by dividing the USEPA RSL by 10 to reflect a HQ of 0.1 to account for potential cumulative effects. The maximum detected concentration of copper (390 mg/kg) does not exceed the unadjusted USEPA RSL (3,100 mg/kg). PR-1012-SD-035 is the only sediment sample to exceed copper screening values in the lagoon. Additionally, there were no exceedances of copper in the surface water samples collected from the lagoon.

The results for tetryl in the demolition samples (PR-0009-CPRE, PR-0010-CPRE, PR-0011-CPRE, PR-0012-CPRE, PR-0013-CPST, PR-0014-CPST, PR-0015-CPST, and PR-0016-CPST) collected from the second demolition at the one demolition site in MRS 09 were rejected. The location will be resampled and results included in the RI report.

Aluminum and copper are not carcinogens. The non-carcinogenic toxicological endpoints of aluminum (neurological) (ATSDR, 2008) and copper (gastrointestinal) (ATSDR, 2004) are not the same (i.e., they affect different target organs). Therefore, aluminum and copper are not expected to exert cumulative effects. Therefore, screening using the unadjusted RSLs is appropriate. An unacceptable risk to human health is not expected from exposure to aluminum and copper in sediment at MRS 09.

The maximum detected concentration of aluminum in sediment at MRS 09 (68,000 mg/kg) only slightly exceeds the BTV for soil (57,000 mg/kg) and the ecological screening value of 280 mg/kg resulting in a HQ of 240.

Two sediment samples were collected at MRS 09, the concentration of copper in one sample (390 mg/kg) slightly exceeds the BTV for copper in soil (310 mg/kg) and exceeds the ecological screening value of 19 mg/kg resulting in a HQ of 21; the selected sediment ecological screening value of 19 mg/kg is the USEPA Region 4 ESV that is based on the threshold effect level applicable to Florida coastal waters, the probable effect level for Florida coastal waters is published as 108 mg/kg.

The naturally occurring concentration of aluminum and copper in Rs soils is high and sediment at MRS 09 was sampled in a collection lagoon that does not have an outfall or discharge in any way to other surface water bodies. Thus, it is likely that naturally occurring metals in the soils from the surrounding hillsides collected in the lagoons surrounding sediment as a result of the erosion from the hillsides. Therefore, elevated concentrations of aluminum and copper in sediment may be a result of the concentration of metals in sediment which collect in a downgradient areas, such as the lagoon sediment, due to erosion, and may not be related to former munitions use at MRS 09.

Additionally, review of studies on range contamination showed that metals were typically of concern at small arms range berm (likely containing Pb) locations with more limited concerns raised at burning ground and deactivation furnaces. All of these situations involve concentrated activities. Metals contamination of concern would not be expected in areas where only diffuse MD was detected since sufficient geoavailable source material would not be available. Cu and

Al are both known to be transported complexed with humic material as colloids. Weathering of shallow bedrock combined with transport via surface water flow to an isolated water body could result in elevated metals concentrations in sediments. The main sources of Al (rockets) and Cu (rotating bands of artillery), are not the same, further indicating MD or MEC to be unlikely sources of these two metals in combination.

During both the 2012 and the 2016/2017 sampling events, evidence of public impacts were observed on the bank of the lagoon and in the lagoon water, as shown in the photos below. Pieces of a motorcycle were observed on the bank, and bottles were observed floating in the water. It is possible public impacts to the lagoon have contributed to localized elevated concentrations of aluminum and copper.

Photograph 7-1: Debris on Bank and in Water of MRS 09 Lagoon

Therefore, based on the results of sampling conducted at this site and evaluation of the surrounding area, aluminum and copper are not considered COPCs in MRS sediment resulting from former munitions use and will not be evaluated further.

Based on the groundwater source evaluation, the maximum concentrations of two metals, chromium (VI) and copper, exceeded their human health screening values and were evaluated in the risk assessment as COPCs. The exposure point concentration of chromium (VI) was determined per the rationale described in Section 4.2.8.4. Copper was evaluated for noncarcinogenic effects; and chromium was evaluated for both noncarcinogenic and carcinogenic effects.

Multiple receptors were identified in the CSM as having potentially complete groundwater exposure pathways at MRS 09. These receptors include: current/future residents, construction/excavation workers, and commercial/industrial workers. Risk results for each receptor are presented below. Tables with risk calculations are located in Appendix P.

Current/ Future Resident

As presented in Table P.8, evaluation of ingestion of groundwater as drinking water results in a cumulative cancer risk of 2E-07 and a Hazard Index (HI) of 0.1, indicating no expected unacceptable risk. The HI represents the cumulative risk for all COPCs detected above screening levels in groundwater within the MRS.

As presented in Table P.9, evaluation of dermal exposure to groundwater results in a cancer risk of 1E-07 and a HQ of 0.0009, indicating no expected unacceptable risk.

Construction/ Excavation Worker

Construction/excavation worker pathways include incidental ingestion and dermal exposure to groundwater.

As presented in Table P.10, the evaluation of incidental ingestion of groundwater results in a cancer risk of 5E-11 and a HI of 0.0006, indicating no expected unacceptable risk.

As presented in Table P.11, the evaluation of dermal exposure to groundwater results in a cancer risk of 2E-10 and a HI of 0.00003, indicating no expected unacceptable risk.

Commercial/ Industrial Worker

Commercial/ industrial worker pathways included: incidental ingestion of groundwater and dermal exposure to groundwater.

As presented in Table P.12, the evaluation of incidental ingestion of groundwater results in a cancer risk of 1E-07 and a HI of 0.07, indicating no expected unacceptable risk.

As presented in Table P.13, the evaluation of dermal exposure to groundwater resulted in a cancer risk of 1E-08 and a HI of 0.0001, indicating no expected unacceptable risk.

7.3.7 MRS 11 North

Based on the soil source evaluation in Subsection 5.4.1.5, the maximum detected concentration of one metal, mercury, was greater than its PSV. Only one sample (PR-1011-S-008) had a concentration (0.4 mg/kg) that exceeded the PSV (0.1 mg/kg). Three additional samples were collected west of sample PR-1011-S-008, but none of these had concentrations that exceeded the PSV. Additional samples were proposed to be collected north, east, and south of sample PR-1011-S-008, but ROE was not obtained for that property. The RI background value established for mercury comparison in DeE2 soil type at MRS 11 is established to be .051 mg/kg. Background values for mercury in other soil types on the island are highly variable and range from 0.032 to 0.6 mg/kg.

The maximum detected concentration of mercury (0.4 mg/kg) did not exceed the human health screening value (1.0 mg/kg); therefore, no risk to human health is expected from exposure to soil at MRS 11.

The maximum detected concentration of mercury does exceed the ecological screening value of 0.1 mg/kg for mercury resulting in a HQ of 4. The maximum detected soil concentration for mercury in the MRS is 0.4 mg/kg. The background value established for mercury comparison in the DeE2 soil type where the exceedance occurs at MRS 11 is 0.051 mg/kg. Background values for mercury are highly variable on the island and range from 0.032 to 0.6 mg/kg. The one soil sample with mercury detected at a concentration above its PSV was in close proximity of three

other samples with mercury detected at concentrations below the PSV. Therefore the mercury exceedance is considered a localized occurrence. The munitions documented as being used on MRS 11 are not known to use mercury fulminate as part of the explosive train. Mercury fulminate is used as an initiating explosive in very small quantities as a primer or detonator. Mercury was identified in the soil but not in conjunction with any other explosive constituents as would be anticipated if it was the result of munition use. The concentration for mercury detected in this one sample is below the background concentration of mercury in at least one soil type found on Culebra Island. For these reasons, it is likely the mercury exceedance is not a result of DoD use of munitions in MRS 11.

Based on the groundwater source evaluation, the maximum concentration of one metal, chromium, exceeded its human health screening value and was evaluated in the risk assessment as a COPC. Chromium was evaluated for both noncarcinogenic and carcinogenic effects.

Multiple receptors were identified in the CSM as having potentially complete groundwater exposure pathways at MRS 11. These receptors include: current/future residents, construction/excavation workers, and commercial/industrial workers. Risk results for each receptor are presented below. Tables with risk calculations are located in Appendix P.

Current/ Future Resident

As presented in Table P.14, evaluation of ingestion of groundwater as drinking water results in a cancer risk of 8E-07 and a HQ of 0.001, indicating no expected unacceptable risk.

As presented in Table P.15, evaluation of dermal exposure to groundwater results in a cancer risk of 6E-07 and a HQ of 0.001, indicating no expected unacceptable risk.

Construction/ Excavation Worker

Construction/excavation worker pathways include incidental ingestion and dermal exposure to groundwater.

As presented in Table P.16, the evaluation of incidental ingestion of groundwater results in a cancer risk of 2E-10 and a HQ of 0.000008, indicating no expected unacceptable risk.

As presented in Table P.16, the evaluation of dermal exposure to groundwater results in a cancer risk of 6E-10 and a HQ of 0.00003, indicating no expected unacceptable risk.

Commercial/ Industrial Worker

Commercial/ industrial worker pathways included: incidental ingestion of groundwater and dermal exposure to groundwater.

As presented in Table P.18, the evaluation of incidental ingestion of groundwater results in a cancer risk of 4E-07 and a HQ of 0.0008, indicating no expected unacceptable risk.

As presented in Table P.19, the evaluation of dermal exposure to groundwater resulted in a cancer risk of 5E-07 and a HQ of 0.00009, indicating no expected unacceptable risk.

7.3.8 MRS 13

The 2007 SI results indicated that chromium exceeded its ecological screening value used in that report, generating an HQ of 42.5. However, when compared to the PSVs used in this risk assessment, the maximum detected concentration for chromium did not exceed the selected

value. Based on the soil source evaluation, explosives were not detected in any soil samples and the maximum detected concentrations of eight metals were not greater than their PSVs. Therefore, MRS 13 was not retained for further consideration in this risk assessment.

Based on the groundwater source evaluation, the groundwater exposure pathway is incomplete for MRS 13 and will not be further evaluated in the risk assessment.

Therefore, MRS 13 was not retained for further consideration in the risk assessment.

7.4 CONCLUSIONS OF THE MC RISK ASSESSMENT

The results of the baseline risk assessment are presented in the following sections. Groundwater sampling conducted to support this Remedial Investigation was conducted to identify impacts from MC; it is not intended to characterize the potability of water throughout Culebra Island.

7.4.1 MRS 06

Based on the results of RI sampling and the geography of the site, MRS 06 was divided into MRS 06 North and MRS 06 South for MC risk assessment purposes. Based on the RI and a review of the MC risk assessment objectives, there is no unacceptable risk attributable to former munitions-related activities at the MRS 06 North or MRS 06 South. No evidence of concentrated munitions use was observed, and therefore no source of MC is present in either area.

No unacceptable risk to human health is expected to occur from exposure to soil, surface water, sediment, or groundwater at MRS 06N or MRS 06S. There is no need to consider dividing MRS 06, based on MC risks.

Based on the analytical results presented for MRS 06 North in this report, barium was detected in surface soil slightly above its ESV for invertebrate receptors.

Historical documentation indicates the only munition fired from MRS 06 containing barium was the Stokes Mortar. The Stokes Mortar was fired from MRS 06 South towards floating water targets in Mosquito Bay. No evidence was found indicating firing was conducted at MRS 06 North in the vicinity of the exceedance. The location of the barium exceedance and the location of the area of the MRS where munitions with barium were fired are on opposite sides of the MRS 06. There is no evidence of heavy munitions use or use of MRS 06 a target area.

Historical documents indicate that the Stokes Mortar which contains a small amount of barium was not fired from or fired to a target area within the vicinity of the barium exceedance and no evidence of concentrated munitions use was observed. Only one munition fragment was discovered which is suspected to be a section of a projectile rotating band. Rotating bands are not associated with mortars, providing further evidence that the exceedance is not the result of Stokes Mortars. Therefore DoD use is not suspected as the likely source of the exceedance and the barium exceedance is likely to be naturally occurring. No unacceptable risk to ecological receptors attributable to MC is expected to occur from to exposure to soil, or surface water. A small risk is present to ecological receptors due to a non-munitions related source of barium.

No unacceptable risk attributable to MC to human health was identified and none is expected to occur at MRS 06 due to exposure to groundwater based on the results of this investigation.

7.4.2 MRS 08

Based on results of this RI and a review of the MC risk assessment objectives, no unacceptable risk to human health or ecological receptors from exposure to soil or sediment at MRS 08 within Culebra Island site was identified. No perennial surface water is present and the groundwater pathway is incomplete.

7.4.3 MRS 09

Based on results of this RI and a review of the MC risk assessment objectives, no unacceptable risk attributable to former munitions-related activities at the site was identified. No evidence of concentrated munitions use was observed, and therefore no source of MC is present.

No unacceptable risk to human health is expected to occur due to exposure to soil, surface water, or sediment at MRS 09.

Based on the analytical results presented in this report, aluminum and copper were detected in sediment above their ecological screening value. However, the naturally occurring concentrations of aluminum and copper in the Rs soil type (from which the sediment is derived) are high and the detected concentrations only slightly exceeded these background levels. The sediment at MRS 09 was sampled in a collection lagoon that does not have an outfall or discharge in any way to other surface water bodies. Thus, it is possible that metals can be concentrated in the collection lagoon due to erosion from surrounding bedrock and soils. Since no evidence of concentrated munitions use was observed, and no explosives detected in soil or water samples, the elevated detections of aluminum and copper in sediment are likely a result of the concentration of metals in sediment which collect in downgradient areas, such as the lagoon sediment, due to erosion, and are not likely to be related to former munitions use at MRS 09. Therefore, based on the results of sampling conducted at this site and evaluation of the surrounding area, aluminum and copper are not considered to pose an unacceptable risk to ecological receptors attributable to MC in the sediment.

No unacceptable risks attributable to MC to ecological receptors due to exposure to sediment were identified, based on results of this investigaton. A small risk is present to ecological receptors due to non-DoD sources of aluminum and copper.

No unacceptable risks attributable to MC to human health due to exposure to groundwater in MRS 09 were identified, based on results of the investigations conducted.

7.4.4 MRS 11

Based on results and conclusions of this RI and a review of the MC risk assessment objectives, no unacceptable risk attributable to former munitions-related activities at the site was identified. No evidence of concentrated munitions use was observed, and therefore no source of MC was identified.

The RI concluded no unacceptable risks to human health due to exposure to surface soil, surface water, or sediment attributable to MCwere identified in MRS 11, based on results of the investigations conducted.

Based on the analytical results presented in this report, mercury detected in surface soil slightly above its ecological screening value was a localized occurrence, is in the range of mercury background concentrations that occur naturally on Culebra Island in other soil types, and is not

considered attributable to military use at MRS 11. The RI concluded no unacceptable risks to ecological receptors due to exposure to surface soil attributable to MC were identified in MRS 11, based on results of the investigations conducted.

Since no significant MC source was identified in soil at MRS 11, no unacceptable risk to human health attributable to MC from exposure to groundwater is identified. Any future groundwater contamination detected downgradient of the landfill would likely be attributable to the Municipality of Culebra, identified as a potentially responsible party, due to use of the unlined landfill. Contamination upgradient or cross gradient of the landfill would not likely be related to the landfill unless it were located immediately adjacent to the landfill.

7.4.5 MRS 13

Based on results of this RI and a review of the MC risk assessment objectives, no unacceptable risks to human health or ecological receptors due to exposure to surface soil at MRS 13 within the Culebra Island site were identified. This is based on the results of the investigations conducted.

7.4.6 MC Uncertainty Assessment

7.4.6.1 Uncertainty in Data Collection and Evaluation

The analysis of uncertainties related to data collection and evaluation focuses on determining whether the available data are representative of site concentrations and site conditions, and whether the features of sampling, analyses, or statistical treatment of the data result in an over- or under estimation of potential risk. The following list addresses potential areas of uncertainty.

- Holding Times

Many samples collected in 2011 and 2012 exceeded their holding times for explosives. All investigative samples and post-detonation samples were re-collected and analyzed for explosives. No holding times were exceeded for investigative samples or post detonation samples in the 2016/2017 re-sampling events.

- Sample Preservation

Most samples collected in 2011 and 2012 were documented above the upper preservation range of 6 °C appropriate for explosives analysis. All investigative and post-detonation samples were re-collected and analyzed for explosives. All cooler temperatures were below 6 °C upon arrival at laboratory in the re-sampling events.

- Analytes that were never detected were eliminated from the risk assessment.

It is possible that some MC may have been present in samples below the reporting limit and not retained in the RA. However, since samples were collected from areas where concentrations were expected to be the highest based on the MEC investigation, and because maximum values were used in comparisons, it is unlikely that any MC were present at health-significant levels.

- Analytes that were below screening levels.

It is possible some analytes may be present onsite in concentrations higher than the screening levels in areas that that were not sampled. These areas could be areas outside the locations called for in the DQOs, or in areas where ROE was not obtained. However, based on analysis of

historical information and the MEC investigation, we feel the risk attributable to former munitions use is characterized correctly.

- Analytes where the LOD exceeded screening levels.

In cases where the laboratory LOD exceeds screening criteria, it is possible analytes are present at levels exceeding screening criteria, but reported as undetected. However, the uncertainty associated with the lack of actual detections is not anticipated to change the conclusions of the RI. This is supported by no findings of concentrated munitions use, and no unacceptable MC contamination in the soil, sediment or surface water from other analytes.

- Representation of background screening levels could be higher or lower than estimated.

To account for this the mean background concentration was multiplied by a factor of 2.

- The RI concluded that the ecological exceedances were not from munitions related sources. Therefore, the exceedances were not carried further in risk assessment.

It is possible that burrowing animals could be exposed to analyte exceedances in the very scarce subsurface soil present onsite.

7.4.6.2 Uncertainty in Exposure Assessment

The exposure assumptions used in the risk assessment were current at the time that the risk assessment calculations were conducted and are consistent with those used by USEPA to generate the May 2012 RSL table. In May 2014, USEPA incorporated updates to the Exposure Factors Handbook into the RSL calculations. These updates to the exposure assumptions are not reflected in this risk assessment. However, incorporation of the updated exposure assumptions to the RSL calculations resulted in generally higher RSLs. Therefore, it follows that if the updated exposure assumptions were used in the risk assessment, the resulting risks would be lower than those calculated in this report. Therefore, the use of the older default exposure assumptions generally overestimate the risk at the site.

7.4.6.3 Uncertainty in Toxicity Assessment

The soil RSLs used in the risk assessment are consistent with those presented by USEPA in the May 2012 RSL table, as they were the most current at the time the risk assessment was completed. Updates to the USEPA RSL table are made semiannually, so the RSLs from the May 2012 RSL table used herein may not represent the most currently available criteria (Specifically, the incorporation of updates to the Exposure Factors Handbook in May 2014 resulting in generally higher RSLs). Therefore, the risk assessment may include COPCs that would not have been included if current RSLs were used and the human health risk may be overestimated.

No background sediment samples could be collected as no suitable lagoon location was identified that is both in an uncontaminated area and receives eroded soil from the same parent rock type upgradient from the lagoon. The Rs soil type is the upgradient soil type eroded and transported into the lagoon in MRS 09, therefore, the Rs soil type was used to represent ambient sediment conditions in the lagoon sampled in MRS 09. It is possible the Rs soil type under represents the true ambient concentrations present.

Some uncertainty is also inherent in the toxicity values used in the groundwater HHRA. Carcinogenic slope factors and route-specific values are derived only for compounds that have been shown to cause an increased incidence of tumors in either human or animal studies. This

dose-response curve is then assumed to be linear at low doses (e.g., those found in situations of environmental contamination) and is used to predict tumor incidence at low exposure levels. When an animal study is used, the final SF is adjusted to account for extrapolation of animal data to humans. If the studies used to derive the SF were conducted for less than the life span of the test organism, the final SF had also been adjusted to reflect risk associated with lifetime exposure.

The carcinogenic slope factors are generally an upper 95th percentile confidence limit of the probability of a response based on experimental animal data in the multistage model. This means that the site-specific chemical risk is not likely to exceed the risk estimate derived through the model and is likely to be less than the predicted risk.

The chronic reference dose (RfD) for a compound is based on studies where either human or animal populations were exposed to a given compound by a given route of exposure for the major portion of the life span (as an USEPA guideline, 7 years to a lifetime) (USEPA, 1989). RfDs are derived by determining dose-specific effect levels from all the available quantitative studies and applying uncertainty factors to the most appropriate effect level to determine an RfD for humans. Uncertainty factors are generally applied as multiples of 10 to represent specific areas of uncertainty in the data. Typically, an uncertainty factor of 100 to 1,000 is used in the professional judgment of uncertainties. General uncertainties in the derivation of RfDs may be associated with factors such as: (1) variations in the general population (to protect sensitive receptors); (2) extrapolation of animal data to humans; (3) use of a subchronic study versus a chronic study to determine the no-observed-adverse-effect level (NOAEL); or (4) use of a lowest-observed-adverse-effect level (LOAEL) versus a NOAEL. Both the uncertainty and modifying factors are conservative in nature and tend to overestimate risk.

7.4.6.4 Uncertainty in Estimating Chemical Risk

The expression of the potential risk associated with contaminants detected at the site is a result of the combined steps of data evaluation, exposure assessment, and toxicity assessment. This combination provides the potential to magnify the uncertainties present in these steps of the HHRA process.

However, screening criteria are developed using very conservative (health-protective) exposure and intake assumptions. The HHRA comparisons also use conservative concentrations of the chemicals detected at the site. Additionally, screening criteria used in the HHRA are considered health-protective for carcinogenic and non-carcinogenic chemical mixtures. Carcinogenic chemicals correspond to the conservative 1×10^{-6} (one in a million) excess cancer risk level, providing a very protective screening value. Non-carcinogens use a target HQ of 1.

7.4.7 Conclusion

Based on the results of the risk assessment for Culebra Island and the analysis of uncertainty, the RI concludes there is no unacceptable risk to human health or ecological receptors attributable to former munitions-related activities at any of the MRSs evaluated in this RI at Culebra Island.

7.5 Risk Characterization for MEC

A baseline MEC HA was completed for the Culebra Island MRS using the MEC HA guidance and accompanying automated scoring worksheets (Appendix L). The MEC HA is completed

only where a confirmed MEC source is present. Therefore, only MRS 08, MRS 09, MRS 11, and MRS 13 are evaluated in the MEC HA. MRS 11 is divided into two areas for assessment purposes, and only the 196.1 acres in the northern portion of the MRS is evaluated in the MEC HA. No MEC hazard was found in the southern 498.2 acres of MRS 11.

The MEC HA addresses the NCP direction for site-specific assessment of risks to human health and the environment. The MEC HA helps a project team understand the hazards associated with a MRS if no action is taken, and to evaluate the hazard reductions associated with removal or remedial alternatives. As with any CERCLA-based cleanup process, several different alternatives may be protective of human health and the environment. The information collected for the MEC HA as well as the results can provide input into the CERCLA remedy evaluation and selection process in the FS phase. The MEC HA presents a number of input factors that are scored based on current site conditions (baseline) and rescored based on proposed remedial alternatives during the FS phase. Based on the input factors for each MRS, the scoring worksheets generate a score for the site based on a sum of the scores determined for each input factor. The sum of the input factor scores falls within one of four hazard levels (1–4). The following description of each hazard level is summarized from the Interim MEC HA Methodology (USEPA, 2008):

Hazard Level 1

This category identifies sites with the highest potential explosive hazard conditions. There may be instances where there is an imminent threat to human health from MEC. This hazard may be so obvious that an emergency response is appropriate without calculating a MEC HA.

Typical characteristics of a Hazard Level 1 site condition include a combination of the following:

- High-explosive-filled UXO, usually "Sensitive UXO" on the surface
- A former target area or OB/OD area
- An MRS with full or moderate accessibility
- Has the presence of additional human receptors inside the MRS or Explosive Safety Quantity-Distance (ESQD)
- May include subsurface MEC with intrusive activities to the depth of subsurface MEC
- An MRS that has not undergone a cleanup.

Hazard Level 2

This Hazard Level identifies MRS with high potential explosive hazard conditions. Typical characteristics of a Hazard Level 2 MRS include the following:

- Former target area, OB/OD area, function test range, or maneuver area
- UXO, or Fuzed Sensitive DMM on the surface, or intrusive activities that overlap with minimum depths of UXO or Fuzed Sensitive DMM located only subsurface
- Has full or moderate accessibility to people who will engage in intrusive activities.

Hazard Level 3

This Hazard level identifies MRS with moderate potential explosive hazard conditions. Typical characteristics of a Hazard Level 3 MRS include the following:

- DMM on the surface, or intrusive activities that overlap with minimum depths of DMM located only subsurface
- Former target area, OB/OD area, function test range, or maneuver area that has undergone a surface cleanup
- An MRS with moderate or limited accessibility, and a low number of contact hours.

Hazard Level 4

This Hazard Level identifies MRS with low potential explosive hazard conditions. The presence of MEC at an MRS means that an explosive hazard may exist. Therefore, MEC may still pose a hazard at a Hazard Level 4 MRS. Typical characteristics of an MRS in Hazard Level 4 include the following:

- A MEC cleanup was performed or MEC is only located subsurface, below the depth of receptor intrusive activities
- Energetic Material Type is propellant, spotting charge, or incendiary
- Accessibility is Limited or Very Limited, and contact hours are few or very few.

7.5.1 Baseline MEC HA Results

A baseline MEC HA was prepared for the Culebra Island MRS based on current site conditions and anticipated future activities. The MEC HA workbooks for each MRS are included as Appendix L. The following paragraphs discuss the baseline MEC HA scores for each MRS.

7.5.1.1 MRS 06 Artillery Firing Area

Because the few MD items discovered in the RI Investigation were anomalous to this MRS, and there have been no documented reports of MEC discoveries or MEC treatment operations by authorities or EOD Teams for the MRS, there is no significant source of MEC hazard proved to exist. MRS 06 is suspected of being used as a firing point and the MEC hazard considered as the most likely source for the MRS would be from DMM, however there were no discoveries or indications of DMM during either the RI or SI field investigations. Therefore, the MEC hazard is considered low and no MECHA has been completed for MRS 06.

7.5.1.2 MRS 08 Cayo Norte Impact Area

Sufficient amounts of MD were found at MRS 08 (shrapnel, rotating bands, and a base plate, from 75mm artillery; along with M1907 fuzes) to confirm the western side of MRS 08 was used as 75 mm artillery target area (from MRS 06 firing points), even if for a short period of time. No MEC or MD items were recovered along the beach areas of MRS 08.

A baseline MEC HA was prepared for MRS 08 based on current site conditions and anticipated future activities. The MEC HA workbook is included as Appendix L. Based upon current site conditions following the RI/FS field effort, MRS 08 scored an 885, which corresponds to a Hazard Level 1.

7.5.1.3 MRS 09 Soldado Point Mortar and Bombing Area

No MEC related to DoD site use was found in MRS 09. Given the presence of expended 4.2-inch mortar fuzes, a potential for human and ecological exposure to HE MEC in MRS 09 exists.

A baseline MEC HA was prepared for MRS 09 based on current site conditions and anticipated future activities. The MEC HA workbook is included as Appendix L. Based upon current site conditions following the RI/FS field effort, MRS 09 scored a 895, which corresponds to a Hazard Level 1.

7.5.1.4 MRS 10 Defensive Firing Area No. 1

Although historical evidence indicates training may have been conducted in the MRS, no MEC or MD were found in the RI investigation. There have been no reports of MEC discoveries or disposal by authorities or EOD Teams for the MRS. There is no evidence to support that an unacceptable hazard is present at the 522 terrestrial acres of MRS 10. Therefore, no MEC HA is conducted for MRS 10.

7.5.1.5 MRS 11 North Defensive Firing Area No. 2

MRS 11 North is located 3,200 feet from the southernmost boundary of the Aircraft Bombing and Machine Gun Range located in the NWP. Aircraft-dropped bombs larger than 500 lb and projectiles larger than 8 in. MD items were used at this range. MD indicative of HE were found in the upland areas of MRS 11 North and also recovered on the beach portions (Tamarindo Beach), which is a popular tourist location.

A baseline MEC HA was prepared for MRS 11 based on current site conditions and anticipated future activities. Intrusive investigations within the southern portion of MRS 11 yielded no MEC or MD finds; however, five grids located in the northernmost portion of MRS 11 did yield MD. These five grids are located adjacent to the NWP area. Therefore, the MEC HA addresses only the northern 196.1 acres of the MRS. The MEC HA workbook is included as Appendix L. Based upon current site conditions following the RI/FS field effort, MRS 11N scored a 930, which corresponds to a Hazard Level 1.

7.5.1.6 MRS 11 South Defensive Firing Area No. 2

No MEC or MD was discovered in MRS 11 South. There is no unacceptable hazard present for residents, recreational users, construction workers, or site visitors within the 498.2 acres of MRS 11 South. There have been no reports of MEC discoveries or disposal by authorities or EOD Teams for the MRS. Therefore, no MEC HA is conducted for the southern 498.2 acres of MRS 11.

7.5.1.7 MRS 13 Cayo Luis Peña Impact Areas

During the post-award site visit, MD items [105 mm (HE and illumination); 5- and 3-inch projectiles; flares; and fuzes] were noted at 112 locations on MRS 13. During the subsequent RI fieldwork, multiple MD items were recovered on MRS 13 including a BDU-33, empty 5-inch illumination projectile and MD fragments.

A baseline MEC HA was prepared for MRS 13 based on current site conditions and anticipated future activities. The MEC HA workbook is included as Appendix L. Based upon current site conditions following the RI/FS field effort, MRS 13 scored an 880, which corresponds to a Hazard Level 2.

An unacceptable MEC hazard is present in MRS 13.

7.5.2 Munitions Response Site Prioritization Protocol

A Munitions Response Site Prioritization Protocol (MRSPP) was prepared for all six of the Culebra Island MRSs as part of the SI Report (Parsons, 2007). Since additional data were collected, the MRSPP provided in the SI Report was re-evaluated and updated in this RI/FS Report to reflect the current understanding of site conditions. The latest version of the MRSPP worksheets was utilized. Table 7-1 provides a summary the MRSPP scored from the 2007 SI Report. Table 7-2 provides a summary of the revised MRSPP results for the Culebra Island MRSs. The revised MRSPP worksheets for the Culebra Island MRSs are provided in Appendix M.

Table 7-1: Summary of the 2007 SI MRSPP

MRS	EHE Rating	CHE Rating	HHE Rating	Overall Rating
06	C	No Known or Suspected CWM Hazard	D	5
08	B	No Known or Suspected CWM Hazard	F	3
09	C	No Known or Suspected CWM Hazard	G	4
10	C	No Known or Suspected CWM Hazard	D	4
11	C	No Known or Suspected CWM Hazard	G	4
13	C	No Known or Suspected CWM Hazard	G	4

Table 7-2: Summary of Revised MRSPP

MRS	EHE Rating	CHE Rating	HHE Rating	Overall Rating
06	E	No Known or Suspected CWM Hazard	No Known or Suspected MC Hazard	6
08	C	No Known or Suspected CWM Hazard	No Known or Suspected MC Hazard	4
09	C	No Known or Suspected CWM Hazard	No Known or Suspected MC Hazard	4
10	No Known or Suspected Explosive Hazard	No Known or Suspected CWM Hazard	No Known or Suspected MC Hazard	No Known or Suspected Explosive Hazard
11 North	C	No Known or Suspected CWM Hazard	No Known or Suspected MC Hazard	4
11 South	No Known or Suspected Explosive Hazard	No Known or Suspected CWM Hazard	No Known or Suspected MC Hazard	No Known or Suspected Hazard
13	C	No Known or Suspected CWM Hazard	No Known or Suspected MC Hazard	4

7.6 MEC HAZARD ASSESSMENT SUMMARY

The potential risk to public safety associated with MEC hazards was characterized for the Culebra Island MRSs. The potential explosive safety risk at MRSs 08, 09, 10, 11N, and 13 are

based on their respective MEC HA baseline condition hazard level scores and the revised MRSPP tables. This characterization is based on current site conditions. If conditions change, the characterization needs to be reevaluated. The information provided in this chapter will be used to provide a baseline characterization for the evaluation of alternatives provided in the FS Report.

In MRS 10 and assessment area MRS 11South, no MEC, no MD, and no evidence of concentrated munitions use indicating a target area were found. There have been no reports of MEC discoveries or disposal by authorities or EOD Teams for either MRS 10 or MRS 11S. A negligible hazard is present in MRS 10 and assessment area 11S, based on historical data and the proximity to other training areas on the island.

In MRS 06, two MD items were found originating from target practice in other MRSs. There have been no reports of MEC discoveries or disposal by authorities or EOD Teams for MRS 06. No historical evidence supports training that would result in a MEC source in the MRS. Two expended projectile casing primers were discovered that supported the potential that DMM may be present per MRSPP guidance; however, there has been no other evidence, historical or physical, that supports the presence of DMM. There is no evidence human receptors are exposed to an unacceptable MEC hazard within MRS 06. Therefore, a negligible MEC hazard is present in MRS 06.

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CHAPTER 8. SUMMARY OF RESULTS

8.1 INTRODUCTION

The initial Culebra Island RI field work was conducted between May and October 2011. In 2013, a groundwater investigation involving a well survey and groundwater sampling was added to the project. Fieldwork for this investigation was conducted in September and December 2013. The RI was developed to identify risks related to MEC and MC within all areas of the sites.

8.2 OBJECTIVES

The primary objective for the RI was to determine the nature and extent of MEC and MC that may be present within the terrestrial boundaries of MRS 06, MRS 08, MRS 09, MRS 10, MRS 11, and MRS 13 on Culebra Island.

8.3 MEC INVESTIGATION ACTIVITIES AND RESULTS

The TPP team agreed that the RI data collection would focus on geophysical (transects and grids) and intrusive investigation of grids in the upland areas, analog intrusive investigations along accessible beaches and in-use trails on MRS 13, and collection of environmental samples at locations in and around areas that represent the highest likelihood for MC contamination, i.e., where MEC or MD is present, at demolition sites, and where there is evidence of low order detonations.

The results for each MRS are reported below.

8.3.1 MRS 06

MRS 06 had both DGM and Analog transects located throughout the site. DGM grids were also placed within MRS 06 in areas identified by the PDT. ROE could not be obtained or was denied in a significant portion of MRS 06, which required the revision of transect placement. In these areas, grids and/or transects were located as close as possible to the original planned locations for grids and transects (based on terrain and available ROE) so as to adequately characterize the area and meet the required acreage identified within the USACE-approved WP.

Anomalies identified by DGM and analog methods were intrusively investigated within the grids. No MEC or MD items were found within MRS 06 during the analog investigations. During the DGM intrusive investigation, four MD items were located and these were identified as two expended artillery primers (specific type unidentifiable), one piece of unidentified fragmentation, and one unidentified MD item (suspected piece of a rotating band).

No target remnants, physical evidence, high density anomaly areas indicating a target area or DoD munitions use was discovered in MRS 06 other than the four MD items. A post-VSP analysis was conducted on the RI data and was used to determine if any significant data gaps in MRS 06 exist that might need further characterization. The VSP analysis requires a munition type as part the input data. During the RI no specific munitions types were identifiable from the 4 MD items found. Thus, munitions suspected to have impacted neighboring MRSs (4.2-inch mortar and 75mm projectile) were used as the input parameters in the VSP analysis. The VSP post-analysis results determined there were no RI data gaps for MRS 06. There have been no

reports of MEC discoveries or disposal by authorities or EOD Teams for MRS 06. There is no evidence human receptors are exposed to an unacceptable MEC hazard within MRS 06.

The fragmentation items are likely the result of munitions detonating in target areas outside of MRS 06 and the fragments landing within the MRS 06 boundary and are, therefore, considered anomalous to this MRS. The low density of the recovered MD in MRS 06 is not indicative of these areas being used as target or impact areas. Firing point locations have been historically documented and there is no historical evidence of MEC discoveries in MRS 06. Therefore, the potential for human receptors to encounter surface or subsurface MEC at MRS 06 is considered negligible.

In addition to the DGM and Analog investigations, the field teams completed 4.36 acres of underwater visual transects exceeding the planned acreage of 4.11 transect acres. The underwater visual transects did not find any evidence of target areas or high munitions use areas (MEC, MD, target remnants, etc.). No historical evidence of surface floating or underwater targets for MRS 06 was found.

Due to the size and geography of the MRS (i.e., Mangrove Bay partially bisects the MRS), it was determined that the receptor populations in the northern and southern portions of the MRS are likely different. Therefore, a separate evaluation of the northern and southern portions of the MRS would provide a more accurate representation of the hazards to human and ecological receptors at this site. Thus, for assessment purposes only, the evaluation of the MRS has been presented separately for MRS 06 North and MRS 06 South. MRS 06 is one MRS and there is no intention to administratively separate MRS 06 into MRS 06 North and MRS 06 South.

MRS 06 is almost entirely privately owned. However, the Commonwealth of PRDNER has jurisdiction over a 1,000 meter wide belt of all Puerto Rico's coastal lands (and additional distances where needed to protect key coastal natural systems), and the territorial waters, including submerged lands beneath them, extending 9 nautical miles offshore. The USFWS is co-manager of the coastal zone as part of the CNWR. Receptors include residents, recreational users, construction workers, and site visitors. The MRS contains several residences scattered throughout the MRS. Portions of the MRS are currently being developed. Increased development in the MRS is likely. Potential receptors include residents, construction workers, on-site workers, recreational users, and trespassers. Access is unrestricted throughout the MRS. Sensitive ecological receptors are present.

The two expended artillery primers found in Grid 6-7 are believed to have originated in MRS 06 but there was no other discoveries in Grid 6-7 to indicate a burial pit, DMM or other indications of a firing point in which a MEC hazard is determined to exist. The low density of the recovered MD in MRS 06 is not indicative of these areas being used as target or impact areas. There is no historical evidence of MEC discoveries in MRS 06 nor was there discoveries of MEC during the RI. Isolated pieces of munitions fragments may be in the MRS originating from munitions that detonated some distance away and outside of the MRS boundary, so their presence does not indicate the presence of a MEC hazard. Because the MD fragments found in MRS 06 were likely from a target outside the MRS (munition body fragment and rotating band fragment) and are considered anomalous to this MRS and the two expended artillery primers were not associated with other discoveries of MEC/MD which would indicate a firing point, there is no significant source of a MEC hazard.

8.3.2 MRS 08

There are sufficient amounts of MD to confirm the western side of MRS 08 was used as a 75 mm artillery target area (from MRS 06 firing points), even if for a short period of time. No MEC or MD items were recovered along the beach areas of MRS 08. Historical ranges shown in relation to the RI MEC investigation for the MRS are shown on Appendix A: Figure A-32.

In accordance with the WP, field teams completed 3.31 acres of underwater visual transects exceeding the planned acreage of 2.32 transect acres. The underwater visual transects did not find any evidence of target areas or high munitions use areas (MEC, MD, target remnants, etc.). No historical evidence of surface floating or underwater targets for MRS 08 was found.

MRS 08 covers all of Cayo Norte, a privately owned island with unrestricted public access. However, to reach the MRS requires a boat, and the vegetation and steep and rugged terrain provide a natural barrier. Potential receptors include residents, construction workers, on-site workers, recreational users, and trespassers. This combination of needing a boat and the nature of the island's land features provides for limiting access to some portions of the MRS. Sensitive ecological receptors are present.

The presence of MD in the upland areas indicates the possibility for an explosive hazard to be present in MRS 08.

The exposure pathway between recreational users and MEC is limited but complete. An unacceptable hazard is present within the entire 306 terrestrial acreage of MRS 08.

8.3.3 MRS 09

Two Mk 25 Marine Markers (reported as MEC) were found on the ground surface near the water in close proximity to each other in MRS 09. Further evaluation indicated the Marine Markers were expended and not likely MEC. However, the shape of the items inhibited full evaluation, therefore the items were destroyed by demolition. Marine Markers are used in both civilian and military marine activity and it is not certain the items were related to DoD site use. The items likely washed on shore after deployment over water. MD consisting of unidentifiable fragmentation, M9 fuze parts, and base plates were also found at the MRS. Historical ranges shown in relation to the RI MEC investigation for the MRS are shown on Appendix A: Figure A-33.

Historical data provided in the Culebra ASR (USACE 1995) and Culebra ASR Supplement (USACE, 2005) for MRS 09 indicate beach F-3 (Point Soldado Beach) was used for mortar, 30 and 50 caliber firing area from boats to shore. Also 30-pound fragmentation bombs and possibly 100-pound demolition bombs were used against silhouette targets on beach F-3. Sueño Cove was a bombing target in which 30-pound and 1,000-pound bombs were dropped against waterborne targets. US Army infantry and US Marine movement exercises and small arms training were conducted on Soldado Point. No targets within the interior acres of MRS 09 were identified in the historical documents and there have been no reports of MEC discoveries or disposal by authorities or EOD Teams for MRS 09. No concentrated munitions use areas (which would indicate a potential for MC contamination) were identified during the RI fieldwork. MD recovered from grids confirms the presence of 4.2-inch HE mortars, given evidence of functioned M9 PD fuzes; however, no evidence of HE aerial bombs was recovered in MRS 09.

In accordance with the WP, field teams completed 3.35 acres of underwater visual transects exceeding the planned acreage of 3.10 transect acres. As indicated previously in this section, historical evidence indicates that Sueño Cove was suspected of containing a bombing target within the underwater acres of MRS 09 and the northwest beach area of Soldado Point was also identified as a mortar target area. The underwater visual transects did not find any evidence of target areas or high munitions use areas (MEC, MD, target remnants, etc.) additional transects were placed within Sueño Cove and along the northwest beach areas but produced no discoveries that indicated DoD munitions use.

MRS 09 is managed by the PRDNER and residential development is not currently allowed on the site; however, several shacks and small structures are present in the southeastern portion of the MRS. Several structures are located in the northwestern portion of the MRS in areas not managed by PRDNER. Potential current and future receptors include residents, construction workers, onsite workers, recreational users, and trespassers. Access throughout the MRS is unrestricted. Sensitive ecological receptors are present.

Given the evidence supporting the presence of expended 4.2-inch mortars, a potential for human and ecologicalan explosive hazard from exposure to HE MEC in MRS 09 exists.

Based on evidence of MEC presence on the MRS and the likelihood of exposure of site visitors to the presence of these items, there is an unacceptable hazard at the 197.4 terrestrial acres of MRS 09.

8.3.4 MRS 10

No MD items were recovered in MRS 10 during the RI; therefore, the potential for humans to encounter MEC at the remaining areas of MRS 10 is considered negligible. Historical training areas shown in relation to the RI MEC investigation for the MRS are shown on Appendix A: Figure A-34.

Historical records indicate that various land areas of MRS 10 were used by the Marine Corps for maneuvers; therefore, potential exposure to an explosive hazard cannot be completely ruled out. However, no evidence was found to indicate an unacceptable hazard is present.

Underwater visual transects did not find any evidence of target areas or high munitions use areas (MEC, MD, target remnants, etc.). There is no historical evidence of surface floating or underwater targets for MRS 10.

MRS 10 is almost entirely privately owned except for municipal lands such as the police and fire stations. Residences are concentrated toward the shoreline along the northern areas of the MRS, and scattered toward the in land in the south eastern areas. Some residential areas have been developed on the hills overlooking the potential mortar impact areas. Increased development is likely in the future. Potential current and future receptors include residents, construction workers, onsite workers, recreational users, and trespassers. Access throughout the MRS is unrestricted. Sensitive ecological receptors are present.

Although historical evidence indicates training may have been conducted in parts for the MRS, no MEC or MD were found in the RI investigation. No unacceptable hazard is present at the 522 terrestrial acres of MRS 10.

8.3.5 MRS 11

Based on differing levels of MEC hazard present in the northern and southern areas of the MRS, MRS 11 is recommended to be divided into two separate MRSs (MRS 11 North and MRS 11 South). The recommended divisions for MRS 11 are located on Appendix A: Figure A-39. Intrusive results for MRS 11 yielded higher densities in grids that were closer to the NWP Bombardment Area. MD items, indicative of HE, were also recovered on the beach portions (Tamarindo Beach), which is a popular tourist location. MRS 11 North is approximately 3,200 feet from the southernmost boundary of the Aircraft Bombing and Machine Gun Range, found in the NWP. Given the proximity to the NWP and the heavy use of NWP, it is likely all MD in MRS 11 North originated from targets at the NWP. One other significant nearby target was discovered outside of MRS 11, a mortar target located on Stream Point. But due to the distance away, and the types of munition used, it is unlikely the fragmentation from target impacted MRS 11. MRS 11 North is within the fragmentation distance of multiple targets on the NWP. These included aircraft-dropped bombs larger than 500 lb and projectiles larger than 8 inches targeting and impacting areas north of the Aircraft Bombing and Machine Gun Range and naval gun safety line found in NWP. Historical ranges shown in relation to the RI MEC investigation for MRS 11 are shown on Appendix A: Figure A-35.

During the visual investigation of the underwater acres of MRS 11 performed with the ROV, an item of interest was identified in MRS 11 South. This item could not be confirmed as munitions-related but will be evaluated along with MRS 12 in an underwater investigation during a separate underwater RI. No MEC or MD were found at the terrestrial acres of MRS 11 South.

The majority of MRS 11 is comprised of private residences and industrial areas. Most development is concentrated in the southern portion of the MRS. Other areas contain undeveloped tracts that are steep with heavy vegetation. Potential current and future receptors include residents, construction workers, onsite workers, recreational users, and trespassers. Access is unrestricted throughout the MRS. Sensitive ecological receptors are present.

Although development is less concentrated in the northern portion of the MRS, access is unrestricted and all receptors mentioned above are present.

There is no unacceptable MEC hazard present for residents, recreational users, construction workers, or site visitors within the 498.2 acres of MRS 11 South.

Given the presence of MD indicative of MEC and the proximity to the NWP where extensive training with HE items was conducted, an unacceptable hazard is present for residents, recreational users, construction workers, or site visitors in the 196.1 acres of MRS 11 North.

8.3.6 MRS 13

During the post-award site visit, MD items [105 mm (HE and illumination); 5- and 3-inch projectiles; flares; and fuzes] were noted at 112 locations on MRS 13 (Appendix A: Figure A-36). During the subsequent RI fieldwork, multiple MD items were recovered on MRS 13, including a BDU-33, empty 5-inch illumination projectile, and MD fragments.

Underwater visual transects were conducted inside of the 100-yd water boundary per the WP (USA 2011) and the PWS to determine if suspected MEC items on the seafloor were present within MRS 13 accessible water areas per the transect design. During the visual investigation

along transects in the North of MRS 13, 39 items were observed that were either suspect MEC or that had the appearance or shape of munitions or MD.

The potential for human exposure to MEC in MRS 13 exists due to the presence of recreational users who frequent the beach areas.

8.4 MC INVESTIGATION ACTIVITIES AND RESULTS

Environmental samples were collected in soil, surface water, and sediment. Soil samples were collected at locations associated with items identified as MEC and MD, and at locations before and after detonations. Background surface soil samples were collected within eight soil types for use in determining background metals concentrations. The soil samples were analyzed for explosives and MC metals. Background surface water samples were collected from Cornello Lagoon in MRS 11. Groundwater samples were collected in MRS 06, MRS 09, and MRS 11. A screening level risk assessment was performed with further evaluation for samples with exceedances.

The MC risk assessment followed a phased approach starting with simple SLRA and moving toward a more complex, site-specific deterministic risk assessment to evaluate the magnitude of the risk at the site. The results of the risk assessment aid in the development, evaluation, and selection of appropriate response alternatives. The following sections summarize the MC characterization results of the RI for each MRS.

8.4.1 MRS 06

A separate evaluation of MC for the northern and southern portions of MRS 06 was completed to provide a more accurate representation of the hazards to human and ecological receptors at this site due to the MRS geography. The MRS is not recommended to be administratively separated on this basis.

There are no exceedances of Human Health screening values, and therefore no unacceptable risks from former DoD munitions use are present to human health from exposure to surface soil at MRS 06.

Historical research indicates that MRS 06 was a firing point with no known targets located within the MRS. Historical documentation indicates the only munition fired from MRS 06 containing barium was the Stokes Mortar. The Stokes Mortar was fired from MRS 06 (south) towards floating water targets in Mosquito Bay. There is no evidence of heavy munitions use or use of MRS 06 as a target area.

Barium was detected in soil at concentrations greater than the ecological screening value. Barium is present at high naturally occurring concentrations in the soils of Culebra, and the maximum concentration detected at MRS 06 (1,100 mg/kg) was only slightly higher than the established naturally occurring background value (710 mg/kg). As noted above, the Human Health screening value (1,500 mg/kg) was not exceeded. Naturally occurring values on the island have a high variability and range from 38 to 960 mg/kg. Since barium does not correlate with former DoD activities within this area of the MRS, it is likely naturally occurring or the result of sources other than DoD munition use. Therefore, the minimally elevated barium concentration is not considered to be related to former military munitions use at MRS 06.

No MC source of release was identified at MRS 06. There is no evidence to indicate risks to human or ecological receptors attributable to MC are present.

8.4.2 MRS 08

There were no exceedances of screening values in the soil samples collected in MRS 08. Therefore no unacceptable risks attributable to MC were identified to human health or ecological receptors from exposure to surface soil in MRS 08.

8.4.3 MRS 09

The RI concluded there are no exceedances of Human Health screening values, and therefore no unacceptable risks to human health from exposure to surface soil, surface water, or sediment attributable to MC were identified at MRS 09, based on the results of this investigation.

The RI also concluded at MRS 09, no unacceptable risks to ecological receptors from exposure to surface soil or surface water attributable to MC were identified, based on the results of this investigation.

Aluminum and copper were detected in sediment at concentrations greater than the respective ecological screening values. The naturally occurring concentration of aluminum and copper in the *Rs* soil type is high. This is the predominant soil type that drains into the lagoon sampled. No suitable locations for background sediment samples were available; therefore, the background values established for soil were used for sediment comparison, which likely underrepresents the true sediment background values. The sediment at MRS 09 was sampled in a collection lagoon that does not have an outfall or discharge in any way to other surface water bodies. Anthropogenic sources (illegally dumped trash and metallic debris) were observed in the lagoon during fieldwork. Thus, it is likely that the naturally occurring elevated concentrations of metals in the soils that eroded from the surrounding hillsides, with added aluminum and copper that sorbed onto sediment particles in transport, collected in the lagoons. The concentrations were likely increased more by aluminum and copper that leached from anthropogenic sources in the lagoon. No explosives were detected in the sediment samples, which further supports the evaluation that the elevated concentrations were not from a MC source. The main sources of aluminum (rockets) and copper (rotating bands from projectiles), are not found in the same munition types (e.g. aluminum is not found in both rockets and projectiles, etc.) further indicating MD or MEC to be unlikely sources of these two metals in combination. There was no physical evidence of rockets or projectile target areas or of any target areas within MRS 09. Historical evidence does not indicated that MRS 09 was ever used as a target area for rockets or projectiles. Thus, based on the results of sampling conducted at this MRS and evaluation of the surrounding area, aluminum and copper are not considered to be related to former munitions use at MRS 09. No unacceptable risks to ecological receptors from exposure to sediment attributable to MC were identified in MRS 09.

No MC source of release was identified at MRS 09. Since there is no MC source present at MRS 09, the RI concluded no unacceptable risks to human health due to exposure to groundwater attributable to MC were identified at the site. This assessment is based on the results of the investigations conducted.

8.4.4 MRS 10

Environmental samples were not collected in MRS 10 since no MEC or MD were found and no evidence of concentrated munitions use was discovered during the RI fieldwork. Given no MC source of release was identified at MRS 10, the RI concluded no risks to human health or ecological receptors attributable to MC were identified for MRS 10. This conclusion is based on the results of the investigations conducted.

8.4.5 MRS 11

There are no exceedances of human health screening values, and therefore the RI concluded no unacceptable risks to human health from exposure to surface soil, surface water, or sediment attributable to MC were identified at MRS 11 North or MRS 11 South. The conclusions are based on the investigations conducted.

Target areas identified through historical research resided solely on the beaches of Firewood Bay and no target areas were placed within the interior of MRS 11. The target areas along the beaches were rocket barrage targets and 81mm mortar targets (the firing point for the 81mm mortars was also located in MRS 11). MRS 11 borders NWP and is approximately 3,200 feet from the southernmost boundary of the Aircraft Bombing and Machine Gun Range that is found in NWP. The Aircraft Bombing and Machine Gun Range boundary crosses the safety line that was established for range use and provided a buffer area to ensure munitions were not fired to the south of the safety line. The NWP Aircraft Bombing and Machine Gun Range targets were established to the north of this safety line. The other significant target outside of MRS 11 was a mortar target on Stream Point but fragmentation from the target is not anticipated to have reached the grids in MRS 11 North where fragments were discovered. The discovery of munition fragments in MRS 11 North is most likely the result of DoD use of the target areas located within NWP and not the result of newly discovered targets on MRS 11 North. MRS 11 North is within the fragmentation distance of aircraft dropped bombs larger than 500 lb and projectiles larger than 8-in. targeting and impacting areas north of the Aircraft Bombing and Machine Gun Range and naval gun safety line boundary (see Appendix A: Figure A-2). Only small quantities of MD (17 pieces of munitions fragments equating to approximately 3.4 lb of MD), were found above the beach areas. The beach areas produced two MD items (an expended BDU 33 and an empty 5-inch illumination projectile. No MEC was discovered and no target remnants or other indicators that would support heavy DoD munitions use. No target areas within MRS 11 were identified.

MRS 11 South produced no MEC or MD. Per the RI WP, if no evidence of munitions-related activities in a given area (e.g., MEC, MD/frag, target berms, ground scars) was identified, then there was no reason to expect that MC would have been released in that area. Therefore, the MC sampling effort that focused on determining the presence of MC contamination associated with evidence of munitions-related activities was not applicable so MC sampling was not conducted in MRS 11 South.

The 2007 SI also supports the RI findings as the SI fieldwork found no MEC in either area; only one MD item in MRS 11 North and no MD in MRS 11 South.

MC sampling of MRS 11 North produced soil samples with detections of mercury with one sample containing mercury concentrations exceeding its PSV. The maximum detected concentration of mercury (0.4 mg/kg) did not exceed the human health screening value

(1.0 mg/kg); therefore, the RI concluded no risks to human health due to exposure to surface soil attributable to MC were identified at MRS 11. The conclusion is based on the results of the investigations conducted.

The background value established for mercury comparison in the DeE2 soil type where the exceedance occurs at MRS 11 is 0.051 mg/kg. Background values for mercury are highly variable on the island and range from 0.032 to 0.6 mg/kg.

Mercury was detected in soil at a concentration greater than the ecological screening value. The one soil sample with mercury detected at a concentration exceeding its PSV was in close proximity of three other samples with mercury detected at concentrations below the PSV; therefore, the mercury exceedance is considered a localized occurrence. The munitions documented as used on MRS 11 are not known to use mercury fulminate as part of the explosive train. Mercury fulminate is used as an initiating explosive in very small quantities as a primer or detonator. Mercury was identified in the soil but not in conjunction with any other explosive constituents as would be anticipated if it was the result of munition use. Mercury fulminate is used in extremely small quantities (usually measured in milligrams per item) as compared to the boosters and main explosive charges of munitions. The boosters and main charges of the munitions represent the majority of the explosive weight. Therefore, since no other explosive constituents were present at the location of the elevated mercury detection, the exceedance is not considered attributable to military munitions use.

Based on the localized occurrence of the exceedance and the concentration falling in the range of mercury background concentrations that occur naturally on Culebra Island in other soil types, the RI concluded no unacceptable risk to ecological receptors is expected to occur from to exposure to soil at MRS 11.

Based on results of the baseline risk assessment and a review of the MC risk assessment DQOs,the RI concluded no unacceptable risks to human health or ecological receptors due to exposure to surface soil, surface water, or sedimentat MRS 11 attributable to MC were identified. The conclusion is based on results of the investigations conducted.

Since there is no significant MC source in soil at MRS 11, the RI concluded there is no unacceptable risk to human health due to exposure to groundwater attributable to MC identified in the MRS. The conclusion is based on the results of the investigations conducted.

8.4.6 MRS 13

There were no exceedances of MC screening values in the soil samples collected in MRS 13. Therefore, the RI concluded no unacceptable risks to human health or ecological receptors attributable to MC were identified in MRS 13. The conclusion is based on the results of the investigations conducted.

No MC source of release was identified at MRS 13. Since there is no MC source in soil at MRS 13, the RI concluded no unacceptable risks to human health attributable to MC due to exposure to groundwater were identified in the MRS.

8.5 USABILITY ASSESSMENT

An evaluation of the existing historical data and data from the SI Report was conducted in the preparation of the Culebra RI/FS WP for the Culebra MRSs. It was determined that there was a

potential for MEC and MC contamination within the investigation areas and additional data were needed to characterize the nature and extent of that contamination. The DQOs as they are presented in Table 3-2 were developed as part of the TPP process to ensure that the data generated as part of RI were of appropriate quality and quantity to support the findings of the RI Report. All DQOs established by the TPP team were met by the RI field effort and risk analysis, documented by the USACE final QA acceptance.

A Quality Control Summary Report (QCSR) was prepared by LDC to review the overall quality of sample results. The QCSR is located in Appendix C, Folder 3 Data Validation and Useability.

Due to exceedences of holding times for extraction of explosives, sample temperatures exceeding 6°C (with some logged in at up to 12°C) upon arrival at the RTI laboratory, and the large number of non-detects, the explosives data for the investigative samples collected in 2011 and 2012 samples is deemed unusable. The investigative samples were recollected and analyzed for explosives. No investigative samples collected in the re-sampling effort exceeded holding times or 6°C. The explosives results collected in 2016 are evaluated as acceptable, and are used in the report.

No holding times were exceeded for metals. Although cooler temperatures upon receipt by the laboratory were logged in at up to 12°C for the 2011/2012 samples, utilizing professional judgement, metals analyses were not validated as qualified since the compounds are not expected to degrade significantly during shipping or storage. The metals results are evaluated as acceptable, and are used in the report.

A comparison of the laboratory LOD to the screening criteria for each analyte in each media identified analytes for which the LOD was not low enough to detect concentrations at the defined screening criteria, i.e., the LOD exceeded the screening criteria. The laboratory instruments were unable to measure the results for these analytes to the screening criteria. In soil, the LOD exceeded the screening criteria for 1,3-Dinitrobenzene. In surface water, the LOD exceeded the screening criteria for 1,3-Dinitrobenzene, 2,4-Dinitrotoluene, 2,6-Dinitrotoluene, Nitroglycerin, and 3-Nitrotoluene. In sediment, the LOD exceeded screening criteria for 1,3-Dinitrobenzene, RDX, Tetryl, HMX, 1,3,5-Trinitrobenzene, and 2,4,6-Trinitrotoluene. In groundwater, the LOD exceeded the screening criteria for 2,4-Dinitrotoluene, 2,6-Dinitrotoluene, 3-Nitrotoluene, Nitrobenzene, and Nitroglycerin. The screening criteria for these analytes are below what is achievable by technology and the implications are discussed in the uncertainty analysis.

Explosives were detected at three locations of the five background samples (Samples: PR-0916-S0026 through -0030 and duplicate of PR-0916-S0030) collected from soil type Ts located in the Tidal Swamp soils within MRS 06. Upon further review, the samples had been placed in a location within 200 ft of a residence. Therefore, the samples collected in 2011 for soil type Ts are not suitable for use as background samples. The background samples were re-collected away from anthropological activity and in an area not known for DoD training. The results from the relocated samples are used as background samples for the Ts soil type. Additional sampling was attempted twice at the original location of the Ts soil background samples to confirm the presence/absence of explosives. However, the location was underwater and the samples could not be re-collected.

The results for Tetryl in post-demolition samples were rejected. The samples were recollected at the demolition location in 2016. The explosives results collected in 2016 are evaluated as acceptable, and are used in this RI report.

The objective of the RI was to determine whether there is sufficient evidence of the presence of MEC and/or MC in the Culebra MRSs 06, 08, 09, 10, 11, and 13 to warrant further action. Relevant data collected from the SI for these MRSs was applied to the RI Report findings when it was applicable to do so. The objective is considered complete when an investigation of MEC and MC is sufficient to characterize the site, identify and quantify any associated risk, and support a FS if significant risks are identified at the site. The DQOs for MEC and MC sampling activities were met.

8.6 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the RI, the following recommendations are made for the terrestrial portions of the six MRSs investigated in this RI, MRS 06, MRS 08, MRS 09, MRS 10, and MRS 11.

8.6.1 MRS 06 - Artillery Firing Area

8.6.1.1 MEC

Based on historical documents there have been no past discoveries of MEC and the RI field work found no evidence to support identification of a MEC hazard at the MRS. MRS 06 is recommended to proceed to an FS, due to a datagap that cannot be resolved due to ROE not granted on some portions of the MRS.

8.6.1.2 MC

Based on results of the baseline risk assessment and a review of the MC risk assessment DQOs, no MC source of release was identified at MRS 06. No risks to human health or ecological receptors attributable to MC related to former military munitions use were identified, based on results of investigations conducted. Therefore, MC will not be evaluated in the FS.

8.6.2 MRS 08 - Cayo Norte Impact Area MEC

8.6.2.1 MEC

The exposure pathway between residents, construction workers, onsite workers, recreational users, and trespassers and MEC is limited but complete. An unacceptable hazard is present within the entire 306 terrestrial acres of MRS 08. MRS 08 is shown in Appendix A: Figure A-32. A FS for development and evaluation of alternatives for a MEC remedial response for the entire MRS is recommended.

8.6.2.2 MC

Based on results of the baseline risk assessment and a review of the MC risk assessment DQOs, no unacceptable risks to human health or ecological receptors attributable to MC related to former military munitions use were identified in MRS 08, based on results of investigations conducted. Therefore, MC will not be evaluated in the FS.

8.6.3 MRS 09 - Soldado Point Mortar and Bombing Area

8.6.3.1 MEC

Two items (expended Mk 25 Marine Markers evaluated as MEC at the time of discovery due to the shape of the item inhibiting full evaluation) were recovered from MRS 09. The items are used in both civilian and military marine activity and it is not certain the items are attributable to military training in the area.

Based on evidence of MEC presence at the MRS and the likelihood of exposure of site users (residents, construction workers, on-site workers, recreational users, and trespassers) to the presence of these items, there is an unacceptable hazard at the 197.4 terrestrial acres of MRS 09. MRS 09 is shown in Appendix A: Figure A-33. A FS for development and evaluation of alternatives for a MEC remedial response for the entire MRS is recommended.

8.6.3.2 MC

Based on results of the baseline risk assessment and a review of the MC risk assessment DQOs, no unacceptable risks to human health or ecological receptors attributable to MC related to former military munitions use were identified in MRS 09, based on results of investigations conducted. Therefore, MC will not be evaluated in the FS.

8.6.4 MRS 10 - Defensive Firing Area No. 1

8.6.4.1 MEC

Although historical evidence indicates training may have been conducted in parts of the MRS, no MEC or MD were found in the RI investigation. No unacceptable hazard is present at the 522 terrestrial acres of MRS 10.

Recommendations from MRS 11 add acreage from the southern terrestrial portion of MRS 11 to MRS 10. The southern 498.2 acres of MRS 11 have been evaluated with no unacceptable MEC hazard present. The acreage recommended for transfer includes the highly developed portions of Dewey and a small portion of the airport. The addition of this acreage would increase MRS 10 from 522 acres (as listed in FUDSMIS) to 1020.2 acres.

No FS is warranted to address MEC hazards at the original acreage of MRS 10 or the acreage transferred into MRS 10 from MRS 11.

8.6.4.2 MC

Environmental samples were not collected in MRS 10 since no MEC or MD and no evidence of concentrated munitions use was discovered during the RI field work. Given no MC source of release was identified at MRS 10, no risks to human health or ecological receptors attributable to MC related to former military munitions use were identified at the 522 acres of MRS 10. The conclusion is based on results of the investigations conducted. A FS to evaluate MC is not warranted.

Given no MC source of release was identified at MRS 11 southern acres, no risks attributable to MC are present to human or ecological receptors at the 498.2 acres of MRS 11 transferred into MRS 10.

A FS to evaluate MC is not warranted for MRS 10.

8.6.5 MRS 11 - Defensive Firing Area No. 2

8.6.5.1 MEC

Based on the differing levels of MEC hazard present in the northern and southern areas of the MRS, MRS 11 is recommended to be divided. Because MD indicative of MEC was recovered only in the northern acreage, and the proximity of the Bombardment Areas of NWP, MRS 11 is recommended to be divided into MRS 11 North and MRS 11 South. The original acreage of MRS 11 and the recommended division of the MRS are shown on Figure 1-3.

The negligible hazard to residents, recreational users, construction workers, and site visitors at the 498.2 acres of MRS 11 South is acceptable; therefore, a FS for MRS 11 South is not warranted. The 498.2 acres of MRS South are recommended to be transferred to MRS 10 (also negligible MEC hazard and similar receptors) located to the south east.

An unacceptable MEC hazard is present in the 196.1 acres of MRS 11 North. Given the presence of MD indicative of MEC and the proximity to the NWP where extensive training with HE items was conducted, an unacceptable hazard is present for residents, recreational users, construction workers, or site visitors. A FS for development and evaluation of alternatives for a MEC remedial response for MRS 11 North is recommended.

8.6.5.2 MC

Based on results of the baseline risk assessment and a review of the MC risk assessment DQOs, no unacceptable risks to human health or ecological receptors attributable to MC related to former military munitions use were identified at MRS 11. The conclusion was based on results of investigations conducted.

Therefore, MC will not be evaluated in an FS for MRS 11 North. A FS to evaluate MC is not warranted for MRS 11 South.

8.6.6 MRS 13 - Cayo Luis Peña Impact Area

8.6.6.1 MEC

The potential for human exposure to MEC in MRS 13 exists for the recreational users who frequent the beach areas. An unacceptable MEC hazard is present in the 334.2 terrestrial acres of the MRS, and therefore, a FS for development and evaluation of alternatives for a MEC remedial response is recommended.

8.6.6.2 MC

Based on results of the baseline risk assessment and a review of the MC risk assessment DQOs, no unacceptable risks to human health or ecological receptors attributable to MC related to former military munitions use were identified at the MRS 13. The conclusion was based on results of the investigatons conducted.

Therefore, MC will not be evaluated in a FS for MRS 13.

Table 8-1 summarizes the MEC and MC terrestrial characterization of the RI and recommendations for the path forward.

As noted above, the conclusions and recommendations of this report apply only to the terrestrial acres of the six MRSs addressed in this RI. Information pertaining to underwater investigation was presented for support of the terrestrial investigation only.

Underwater visual transects were conducted inside of the 100-yd water boundary per the WP (USA 2011). This aided in determining if suspected MEC items on the seafloor were present within the MRS accessible water areas per the transect design. The visual investigation along transects for MRS 11 and MRS 13 found either suspect MEC items or items that had the appearance or shape of munitions or MD. No suspect MEC items or items of interest were found in MRS 06, 08, 09, and 10. The underwater portions of MRS 09 and MRS 13 are evaluated in a separate RI/FS. MRS 12 encompasses the underwater acres of MRS 10 and 11 (ocean side of the MRSs) is also investigated and evaluated by a separate RI/FS. The bay side underwater acres of MRS 10 and MRS 11 along with underwater acres of MRS 06 and 08 currently have not been identified for an RI/FS.

Table 8-1: MEC and MC Terrestrial Characterization Summary

MRS	Land Use		Unacceptable MEC Hazard Present? (1)	Unacceptable MC Risks Present? (2)	FS Recommended?
	Current/Future	Accessibility			
MRS 06 (826 acres)	Residential / Residential	Limited Steep, rugged terrain and vegetation limit access to the interior	Unknown (MD) Unresolveable datagap due to ungranted ROE.	Unknown, but likely not.	Yes FS for evaluation of remedial alternatives for potential MEC hazard.
MRS 08 (306 acres)	Part-Time Residential / Residential or Resort	Limited (by boat only, steep rugged terrain)	Yes (MD)	No	Yes FS for evaluation of remedial alternatives for MEC hazard.
MRS 09 (197.4 acres)	Nature Preserve, Residential / Residential or Resort	Limited Steep, rugged terrain and vegetation limit access to the interior	Yes (MEC MD)	No	Yes FS for evaluation of remedial alternatives for MEC hazard.
MRS 10 (522 acres) If MRS 11 South transferred in: (1020.2 acres)	Residential / Residential	Full, Unlimited	No	No	No No unacceptable MEC hazard or MC risk identified.
MRS 11 North (196.1 acres)	Mixed Residential, Landfill / Mixed Residential, Landfill	Limited Steep, rugged terrain and vegetation limit access to the interior	YES (MD)	No	Yes FS for evaluation of remedial alternatives for MEC hazard.
MRS 11 South (498.2 acres)	Mixed Residential/ Mixed Residential	Limited Steep, rugged terrain and vegetation limit access to the interior	No	No	No No unacceptable MEC hazard or MC risk identified. Recommend transfer to MRS 10.
MRS 13 (334.2acres)	Nature Preserve / Nature Preserve	Limited Steep Terrain and vegetation limit access to the interior (by boat only)	Yes (MD)	No	Yes FS for evaluation of remedial alternatives for MEC hazard.

(1) No evidence of concentrated munitions use found in any MRSs investigated.

(2) No unacceptable MC risks identified to human health or ecological receptors in MRS 06, MRS 08, MRS 09, MRS 10, MRS 11 or MRS 13. Therefore, no evaluation of MC in an FS is warranted.

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CHAPTER 9. REFERENCES

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