National Aeronautics and Space Administration

Final

Feasibility Study

Operable Unit 8
Formerly Used Defense Sites
Project 9
Skeet Range Munitions Response Site

Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia

February 2022

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FINAL

FEASIBILITY STUDY

OPERABLE UNIT 8
FORMERLY USED DEFENSE SITES
PROJECT 9
SKEET RANGE MUNITIONS RESPONSE SITE

Submitted to:
National Aeronautics and Space Administration
Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

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LIST OF ACRONYMS AND ABBREVIATIONS

µg	Microgram
µg/dL	Microgram per deciliter
µg/kg	Microgram per kilogram
µg/L	Microgram per liter
AA	Area of Attainment or Attainment Area
AGTR	Aircraft Gun Testing Range
ALM	Adult Lead Methodology [model]
AOC	Area of Contamination
ARARs	Applicable or Relevant and Appropriate Requirements
BCY	Bank cubic yard
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	Cubic foot
CFR	Code of Federal Regulations
COC	Chemicals of Concern
COPC	Chemical of Potential Concern
CSM	Conceptual Site Model
CSF	Cancer Slope Factor
CY	Cubic yard
dL	Deciliter
DRO	Diesel range organics
E&S	Erosion and sediment
EEQ	Ecological Effects Quotient
ELUR	Environmental Land Use Restriction
EPC	Exposure point concentration
EPA	[United States] Environmental Protection Agency
ERA	Ecological risk assessment
$foot^2$	Square foot
FS	Feasibility Study
FUDS	Formerly Used Defense Sites
GRA	General Response Actions
GSFC	Goddard Space Flight Center
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HHRA	Human Health Risk Assessment
HI	Hazard Index
IC	Institutional Control
ICLR	Incremental Lifetime Cancer Risk
IDIQ	Indefinite Delivery Indefinite Quantity
IEUBK	Integrated Exposure Uptake Biokinetic [model]
L	Liter
LCY	Loose cubic yard
LDR	Land Disposal Restriction
LOEC	Lowest observed effect concentration
LOAEL	Lowest observed adverse effect level
LTM	Long-term monitoring

LUC	Land Use Control
LS/foot^2	Lead shot per square foot
MBFR	Main Base Firing Range
MC	Munitions constituents
MCL	Maximum Contaminant Level
MEC	Munitions and explosives of concern
mg	Milligram
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
mm	Millimeter
MOA	Memorandum of Agreement
MRS	Munitions Response Site
MRSPP	Munitions Response Site Prioritization Protocol
O&M	Operation and maintenance
OMB	[White House] Office of Management and Budget
OSHA	Occupational Safety and Health Administration
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NCP	National Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NOEC	No observed effects concentration
NTCRA	Non-time critical removal action
PAHs	Polycyclic aromatic hydrocarbons
PPE	Personal protective equipment
PRAP	Proposed Remedial Action Plan
PRG	Preliminary Remediation Goal
PV	Present Value [cost]
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RD	Remedial design
RfD	Reference Dose
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROD	Record of Decision
RPM	Remedial Project Manager
RSL	Regional Screening Levels
SI	Site Inspection
SY	Square yard
TAL	Target Analyte List
TBD	To be determined
TBC	To Be Considered [guideline, value, etc.]
TCLP	Toxicity Characteristic Leaching Procedure
TPH	Total petroleum hydrocarbons
TRZ	Target Remediation Zone
TSD	Treatment, storage, and disposal [facility]
U.S.	United States
USACE	United States Army Corps of Engineers
USC	United States Code
USEPA	United States Environmental Protection Agency

USFWS	United States Fish and Wildlife Service
UU/UE	Unlimited use and unrestricted exposure
VDEQ	Virginia Department of Environmental Quality
VDHR	Virginia Department of Historic Resources
WFF	Wallops Flight Facility

EXECUTIVE SUMMARY

This Feasibility Study (FS) report addresses human health and ecological risks associated with Chemicals of Concern (COCs) and lead shot in soil at the Operable Unit 8 Formerly Used Defense Site (FUDS) *Skeet Range Munitions Response Site (MRS)* of the *Main Base Firing Range (MBFR) Complex* at National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) Wallops Flight Facility (WFF) located in Accomack County, Virginia. WFF comprises the Main Base, Mainland, and Wallops Island (Figure 1-1). The Main Base measures approximately 2,000 acres and is located near the intersection of Virginia Routes 798 and 175. The Town of Chincoteague is located 5 miles east of the Main Base.

The MBFR Complex is in the northern portion of the Main Base, measures approximately 40 acres, and encompasses the former Pistol Range, former Rifle Range, former Aircraft Gun Testing Range (AGTR), and the Skeet Range MRS. The Skeet Range MRS comprises several former skeet ranges at the Complex. The buildings and shooting stations associated with the Complex no longer exist. The AGTR, Pistol Range, and Rifle Range were investigated and addressed previously under separate actions.

The MBFR Complex is on a peninsula-like feature adjacent to Little Mosquito Creek. The southern half and the central portion of the Complex are mostly grassy and flat, with little slope. The perimeter of the Complex consists of gentle slopes ranging from 1 to 4 percent to the northwest, north, and east. There are no streams within or adjacent to the MBFR Complex and drainage is via overland sheet flow. Southern and eastern downrange portions of the former east-facing skeet range drain into a centralized collection area where surface runoff is directed through a concrete drainage culvert and into a drainage swale that discharges to Little Mosquito Creek and associated wetlands. Vegetation on the northern and eastern portions of the site consists of conifers, bushes, and tall grasses. Most soil encountered at the site during the environmental investigations was silty fine-grained sand with varying amounts of organics and trace amounts of medium to coarse-grained sand. The Complex area is undeveloped and industrial and will remain so because of building height and occupancy restrictions. No future residential uses are planned for this area. These restrictions are in place due to the proximity of the active airport runways, which are important to the facility's mission.

A Site Investigation was performed in 2007 at the MBFR Complex (Tetra Tech, 2009). Additional soil samples were collected and analyzed for lead in 2009 from the drainage swale leading to Little Mosquito Creek to address a data gap. In 2010 the United States Army Corps of Engineers (USACE) conducted further historical review of the Complex under the guise of a Site Inspection (SI) (USACE, 2012). Removal actions were performed for the former AGTR, Pistol Range, and Rifle Range in 2016. A Remedial Investigation (RI) was conducted in 2019 for the remainder of the Complex (i.e., the subject Skeet Range MRS components) to refine the delineation of contaminated surface soil, investigate potential contamination in subsurface soils, collect data to confirm and further develop preliminary remediation goals (PRGs), and re-evaluate risks to human health and ecological receptors (Tetra Tech, 2020).

The RI Report included a human health risk evaluation of exposure to potential contaminants in surface and subsurface soil. No other medium presents a complete exposure pathway. Risks were identified for industrial and hypothetical residential receptors exposed to lead and polycyclic aromatic hydrocarbons (PAHs) in surface and subsurface soil with many uncertainties noted. The RI Report also included a screening-level ecological risk assessment (ERA) of exposure to potential contaminants in surface and shallow subsurface soil. No other medium presents a complete ecological exposure pathway. Some surface soil in the drainage area and wetland leading to Little Mosquito Creek was evaluated as sediment in the ERA. The potential ecological receptors at the site include terrestrial plants, soil invertebrates, sediment invertebrates, insectivorous birds and mammals, and herbivorous birds and mammals. Risks were identified for terrestrial plants, soil invertebrates, sediment invertebrates, and insectivorous birds exposed to lead in surface and shallow subsurface soil with many uncertainties noted. Risks also were identified for birds due to lead shot in the soil.

The remedial action objectives (RAOs) developed in this FS for the Skeet Range MRS are as follows:

- Reduce unacceptable risks due to the residential and industrial exposure to lead and PAHs in soil above the cleanup levels.

- Reduce unacceptable risks to ecological receptors from exposure to lead in soil and sediment above the cleanup levels.

- Reduce unacceptable risks to ecological receptors from exposure to lead shot in soil above the cleanup level.

- Reduce migration of lead from upland soil to sediment in Little Mosquito Creek at levels that cause unacceptable risk to the environment.

The COCs—lead, PAHs, and lead shot—are present at concentrations or counts that exceed the PRGs. Remedial alternatives were developed from applicable technologies to meet the RAOs and address COCs present at levels exceeding PRGs. The remedial action alternatives evaluated for soil/sediment in this FS are as follows:

- Alternative 1–No Action.

- Alternative 2–Excavation and Off-Site Disposal.

- Alternative 3–Excavation, On-Site Consolidation, Soil Cover, Operation and Maintenance (O&M), and Land Use Controls (LUCs).

Regulatory input on the evaluated alternatives is obtained during the review process for this document, prior to the recommendation or selection of a preferred alternative. A Proposed Remedial Action Plan will be drafted to present NASA's preferred alternative following the review and finalization of this FS report. A public meeting and public comment period will be held to solicit comments from the public on the preferred alternative for the Skeet Range MRS.

1.0 INTRODUCTION

This Feasibility Study (FS) report was prepared by Tetra Tech to address human health and ecological risks associated with Chemicals of Concern (COCs) in soil at the Operable Unit 8 Formerly Used Defense Site (FUDS) Skeet Range Munitions Response Site (MRS) of the Main Base Firing Range (MBFR) Complex at National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's (GSFC's) Wallops Flight Facility (WFF) located in Accomack County, Virginia (Figure 1-1). This document was prepared under Indefinite Delivery Indefinite Quantity (IDIQ) Contract No.80KSC019D0011 / 80GSFC21F0113, Task Order (TO) 23 for NASA's use and submittal to the United States (U.S.) Environmental Protection Agency (EPA or USEPA) Region 3 and the Virginia Department of Environmental Quality (VDEQ). These agencies work jointly with NASA as the *Remedial Project Manager (RPM) Team* to address environmental restoration issues under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regulatory framework.

This FS was developed in accordance with CERCLA[1] requirements (as amended) and implemented by the National Oil and Hazardous Substances Pollution Contingency Plan (National Contingency Plan [NCP]),[2] USEPA's (1988) Remedial Investigation (RI) and FS guidance, and other relevant USEPA guidance. Consistent with the CERCLA process, this FS will support the selection of a preferred remedy. The preferred remedy will be determined by the RPM Team and presented in a Proposed Remedial Action Plan (PRAP) for public review and input, followed by a Record of Decision (ROD) to document the selected remedy.

1.1 OBJECTIVES AND APPROACH

This FS report presents the conceptual site model (CSM), development of remedial action objectives (RAOs), selection of COCs and Preliminary Remediation Goals (PRGs),[3] and an evaluation of remedial alternatives based on the results and conclusions of the RI Report (Tetra Tech, 2020). The FS discusses the criteria used to evaluate remedial alternatives and to determine the benefits of implementing them. Pursuant to the NCP and USEPA (1988) RI/FS guidance, the remedial alternatives are evaluated according to their ability to meet the following nine NCP criteria:

Threshold Criteria

1. Overall protection of human health and the environment
2. Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

Primary Balancing Criteria

3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility, or volume through treatment
5. Short-term effectiveness
6. Implementability
7. Cost

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[1] CERCLA: 42 U.S. Code (USC) §§ 9601 et seq.
[2] The NCP is detailed in Title 40 of the Code of Federal Regulations (CFR), Part 300 (40 CFR 300).
[3] Final remediation goals (cleanup levels) are established in the ROD.

Modifying Criteria

8. State acceptance
9. Community acceptance

The modifying criteria are evaluated after regulatory agency and public comments are received on the FS and PRAP. Green and sustainability elements may also be considered during evaluation of the remedial alternatives.

The RPM Team will use the information presented and referenced herein to choose the preferred remedial alternative for soil. The FS report is not intended to serve as a design document; rather, it gives a conceptual overview of remedial alternatives and an assessment of their feasibility for the site-specific conditions at the site. A copy of NASA's Administrative Record File for WFF, which contains historical environmental restoration documents for the site and facility, may be reviewed via computer access at the following locations:

Eastern Shore Public Library	Island Library
23610 Front Street	4077 Main Street
Accomack, Virginia 23301	Chincoteague, Virginia 23336
(757) 787-3400	(757) 336-3460

Documents which are made available for public review and comment are accessible at these locations.

1.2 REPORT ORGANIZATION

This report is organized in sections and appendices as shown in the Table of Contents. Facility background and site information are presented in the remainder of Section 1.0. Section 2.0 discusses the development of RAOs. Section 3.0 identifies and screens remedial technologies that are available. Section 4.0 provides a description and detailed analysis of remedial alternatives for consideration. Section 5.0 contains the references cited in this report. Tables and figures are provided after Section 5.0. Appendices are provided electronically on the enclosed CD or DVD.

1.3 BACKGROUND

This section provides a summary of facility and site-specific background information. Additional details are available in the Tetra Tech (2020) RI Report and other referenced historical reports.

1.3.1 Facility Background

WFF comprises three land parcels in Accomack County, Virginia (Figure 1-1): Main Base, Mainland, and Wallops Island. The Main Base is approximately 2,000 acres in size and is near the intersection of Virginia Routes 798 and 175. The Town of Chincoteague is located 5 miles east of the Main Base.

NASA or its predecessor, the National Advisory Committee for Aeronautics (NACA), have had a presence at WFF since 1945. NACA established a rocket launch site on the southern portion of Wallops Island (Wallops Station) in 1945 under the direction of the Langley Research Center and launched its first rocket that year. NASA expanded its presence at WFF with the acquisition of the Main Base and Mainland parcels in 1959. The mission of WFF has undergone several changes since it was established in 1959, but the focus has been and continues to be rocket research, the management of suborbital projects, suborbital and orbital tracking, aeronautical research, and space technology research. NASA does not manufacture rockets, rocket fuels, or rocket propellants at WFF. Rocket motors are transported to the facility from other government facilities.

1.3.2 Site Background

The MBFR Complex is in the northern portion of the Main Base, directly north of the intersection of Runway 10-28 and Runway 17-35 (Figures 1-1 and 1-2). The MBFR Complex measures approximately 40 acres considering all its components: Former Pistol Range, former Rifle Range, former Aircraft Gun Testing Range (AGTR; also known as the Machine-Gun Range), and the Skeet Range MRS (Figure 1-2). The buildings and shooting stations associated with the MBFR Complex no longer exist. The former High Tower Range (former northeast-facing skeet range; also known as the Shotgun Range) is part of the Skeet Range MRS. The former Rifle Range was a component of the Skeet Range MRS for U.S. Army Corps of Engineer (USACE) FUDS Project 9–Main Base Range. NASA took on responsibility for environmental restoration work for FUDS Project 9 from USACE in 2015 following the Site Inspection (SI) Report (USACE, 2012) and Memorandum of Agreement (MOA) with the Department of Army.

The Skeet Range MRS comprises two former skeet range configurations. The first skeet range—called either the Shotgun Range or High Tower Range—was constructed in 1944 with a northeast direction of fire. Sometime between 1945 and 1948, the High Tower Range was replaced with a reconfigured skeet range with an east direction of fire: The east-facing skeet range (Figure 1-2). Collectively these are the Skeet Range MRS and are the remaining area of the MBFR Complex to be addressed under CERCLA. Most of the original High Tower Range is overlapped by the former east-facing skeet range, Rifle Range, Pistol Range, and AGTR. The High Tower Range includes a 500-foot danger zone and the east-facing skeet range includes a 900-foot safety fan.

The AGTR was constructed in 1944 after the completion of the airfield runways; it was converted into the Pistol Range in 1948. The Rifle Range was constructed adjacent-east to the Pistol Range in 1951 (USACE, 2005). The AGTR, Pistol Range, and Rifle Range were investigated and addressed previously by non-time-critical removal actions (NTCRAs) in 2016 (Tetra Tech, 2017).

The RI for the Skeet Range MRS divided the site into four *exposure areas* for purposes of discussion and evaluation (Figure 2-2) (Tetra Tech, 2020): High Tower Range Exposure Area, Northern Range Exposure Area, Southern Range Exposure Area, and Skeet Range Shooting Exposure Area. These exposure areas are maintained in the FS to facilitate discussion and evaluation for remedial action.

The National Oceanic and Atmospheric Administration (NOAA) operates their Command and Data Acquisition Station at WFF in a compound [leased from NASA] east of the MBFR Complex (Figure 1-2 and see inset picture, right). This facility ensures scheduled data flow from NOAA satellites. The most visible features are the many radar dish antennae. The compound is enclosed by a chain link fence and drainage swales. The soil was reworked along this boundary as the compound expanded over the years (most recently in 2011 during construction of a new antenna tower). The NOAA facility is not included in the exposure areas because it has been significantly reworked since the Skeet Range MRS was last operational.

1.3.2.1 High Tower Range Exposure Area

The High Tower Range Exposure Area is north and northwest of the NOAA facility and comprises two portions of the former High Tower Range that (i) are outside of the NOAA facility and (ii) were not addressed by the NTCRAs in 2016 for the former AGTR, Pistol Range, and Rifle Range (Figures 1-2 and 1-3). The High Tower Range Exposure Area is old field grasslands and deciduous scrub. The soil in this exposure area is described as Molena loamy sand soil and transitions north to Chincoteague silt loam soil (Tetra Tech, 2004).

1.3.2.2 Northern Range Exposure Area

The Northern Range Exposure Area is north of the NOAA facility and encompasses the northern portion of the former east-facing skeet range (Figures 1-2 and 1-4). The Northern Range Exposure Area is almost entirely a drainage swale of deciduous scrub leading to a palustrine forested wetland. The drainage swale conveys runoff north through the wetland to Little Mosquito Creek. A culvert located on the NOAA facility connects the southern and northern portions of the east-facing Skeet Range. The soil in this exposure area is described as Molena loamy sand soil and transitions north to Chincoteague silt loam soil (Tetra Tech, 2004).

1.3.2.3 Southern Range Exposure Area

The Southern Range Exposure Area is west and southwest of the NOAA facility and encompasses the southern portion of the former east-facing skeet range (Figures 1-2 and 1-5). This includes the area cleared by NOAA in 2011 during antennae tower construction (now a loblolly pine forest) and a flat grassy area (mowed). The Skeet Range Shooting Exposure Area is within the Southern Range Exposure Area. The soil in this exposure area is described as Bojak fine sandy loam soil (Tetra Tech, 2004).

1.3.2.4 Skeet Range Shooting Exposure Area

The Skeet Range Shooting Exposure Area is the area of the firing line and shooting stations of the former east-facing skeet range within the Southern Range Exposure Area (Figures 1-2 and 1-6). This exposure area was established in the RI to evaluate risks from polycyclic aromatic hydrocarbons (PAHs). The soil in this exposure area is described as Bojak fine sandy loam soil (Tetra Tech, 2004).

1.3.3 Previous Investigations and Actions

The MBFR Complex has undergone several investigations and removal actions. The locations of historical samples for the Skeet Range MRS are shown on the figures for each exposure area on Figures 1-3 through 1-6. Historical analytical data figures and tables are provided in Appendix A.

1.3.3.1 Site Investigation (2007-2009)

A Site Investigation was performed in 2007 as the initial investigation at the MBFR Complex (Tetra Tech, 2009a). The objectives were to characterize surface soil and shallow groundwater conditions, as well as potential drainage pathways. A habitat assessment also was conducted.

Soil sampling was conducted at the east-facing skeet range (i.e., parts of the Northern and Southern Range Exposure Areas) for analysis of PAHs, pH, total organic carbon, Target Analyte List (TAL) metals, and grain size. Lead shot counts were also performed. Lead concentrations in soil ranged from 6.9 to 1,150 milligrams per kilogram (mg/kg), with the highest concentrations within the drainage swale of the Northern Range Exposure Area. Lead shot was not observed in the Northern Range Exposure Area. Lead shot was identified at many locations in the Southern Range Exposure Area with counts ranging from 0 to 165 lead shot per square foot (LS/foot^2) (from 0 to 6 inches deep). The areas with the greatest amount of lead shot were identified in the southern and southeastern downrange portions of the Southern Range Exposure Area in the flat grassy areas, generally within 600 feet of the firing area. The lead shot was found to be in good condition with no fragmentation and very little oxidation. PAH concentrations were highest in soil samples from the Skeet Range Shooting Exposure Area, specifically in areas adjacent to and within about 120 feet of the firing line or shooting stations. Total PAH concentrations ranged from 17.2 to 275,080 micrograms per kilogram (µg/kg). Locations with observed clay pigeon fragments coincided with samples exhibiting higher PAH concentrations.

Five shallow temporary monitoring wells were installed and sampled across the Complex. Two (RRMW-02 and RRMW-03) of the five wells were located within the Skeet Range MRS addressed in this FS. They were installed and sampled for PAHs and TAL metals. PAHs were not detected, and lead concentrations were below USEPA tap water risk-based screening levels. Iron and manganese were detected above risk-based screening values in well RRMW-03. However, the concentrations were deemed to be within the range of background concentrations detected in groundwater samples from across the Main Base (Tetra Tech, 2004). The report noted silty to heavy/hard grey clays at depths greater than 6 feet at well RRMW-03 during its installation (not present at RRMW-02), contributing to higher turbidity and total metals concentrations. In addition to the higher turbidity, the sample from RRMW-03 contained a very low level of oxygen. The concentrations appear to be related to the geochemistry (reducing conditions) and geology (clayey silt) at this well location. The Site Investigation Report recommended that no further evaluation of groundwater was necessary, but additional investigation or action was warranted to address potential risks associated with PAHs and lead in soils.

The Site Investigation Report included human health and ecological risk evaluations. The report concluded unacceptable carcinogenic risk from PAHs to hypothetical residents but not to industrial workers. Lead concentrations above the residential screening level of 400 mg/kg and the industrial screening level of 800 mg/kg (USEPA Region 3 Regional Screening Levels [RSLs]) indicated potential adverse non-cancer effects. The ecological risk evaluation concluded potential risk to insectivorous receptors exposed to lead in soil and to birds ingesting lead shot. The report recommended further actions to address PAH and lead levels in soils adjacent to the north and southeast of the former firing line of the east-facing skeet range.

1.3.3.2 Supplemental Soil Sampling in Drainage Area (2009)

Supplemental soil sampling efforts occurred in the Northern Range Exposure Area in 2009 (Tetra Tech, 2009b). Surface soil samples were collected and analyzed for lead from the drainage swale. No lead shot was observed in these samples. Lead concentrations in the soil range from 325 to 1,400 mg/kg. The data summary report did not provide evaluation or conclusions.

1.3.3.3 Site Inspection (2010)

In 2010, the USACE conducted an SI, which is a required step in USACE's FUDS program environmental restoration [CERCLA] process, especially for sites known or suspected of containing unexploded ordnance, discarded military munitions, or munitions constituents (MC) (USACE, 2012). The SI included records research, other desktop study elements, and munitions and explosives of concern (MEC) and MC evaluations; no fieldwork or environmental sampling was performed as part of the SI. The RPM Team agreed that any potential MEC hazard at the Skeet Range MRS relates only to intact or unfired small arms munitions (which have a low explosive hazard). Therefore, it was agreed that MEC reconnaissance would not be necessary given the site's history as a skeet range and the present land use.

The records research identified the existence of the northeast-facing High Tower Range. The report summarized the site history, new records research, environmental investigation data collected to date and conclusions from the data, and the Munitions Response Site Prioritization Protocol (MRSPP) rating. The report acknowledged the presence of MC, stated the absence of chemical warfare material, and described the relative MEC hazard—the site was assigned a draft MRSPP rating of "Priority 5." The report concluded the site is an "important ecological place" and sensitive environment due to the presence of wetlands and proximity to Little Mosquito Creek. The report recommended an RI for the Skeet Range MRS, including the northeast-facing skeet range (i.e., High Tower Range Exposure Area) and drainage area (i.e., Northern Range Exposure Area).

1.3.3.4 NOAA Antennae Tower Construction (2011)

In 2011, NASA collected soil samples for total lead and Toxicity Characteristic Leaching Procedure (TCLP) lead analysis—from the eastern portion of the Southern Range Exposure Area—to support NOAA construction of two new antenna towers, which would encroach on the former east-facing skeet range. The soil lead concentrations from this NOAA-related sampling event range from 36.9 to 157 mg/kg, below the residential RSL of 400 mg/kg. TCLP results from the event do not indicate hazardous characteristic lead levels (less than 5 milligrams per liter [mg/L]). NOAA has since cleared the trees and constructed on the new antennae sites (i.e., "NOAA Antennae Site 8" and "Site 5" shown on Figure 1-2).

1.3.3.5 Memorandum of Agreement (2015)

Further investigation at the Skeet Range MRS was put on hold in 2010 for USACE to complete the SI and for USACE and NASA to resolve their respective roles and responsibilities under the FUDS program. In 2015, an MOA was entered into between the Army and NASA regarding environmental restoration work at certain locations on WFF, including the Skeet Range MRS. The MOA documents that NASA, as the land holding agency of WFF, is the most suitable agency to conduct all response actions on the facility under CERCLA or the Resource Conservation and Recovery Act (RCRA). As such, the environmental response at the Skeet Range MRS (FUDS Project 9) is being conducted by NASA and addressed by this FS.

1.3.3.6 Remedial Investigation (2018-2020)

RI activities were performed at the site in 2018 through 2019 to meet the following objectives, which were achieved according to the RI Report (Tetra Tech, 2020): Further delineate the extent of contaminated surface soil; investigate potential contamination in subsurface soils; collect data to confirm COCs and develop PRGs, and reevaluate risk to human health and ecological receptors. Surface and subsurface soil samples were collected in all the exposure areas and analyzed for lead. Samples in the Skeet Range Shooting Exposure Area were analyzed for PAHs. Surface soil was also sieved at many locations throughout the site to determine counts of lead shot, clay pigeon fragments, and grit particles.

The results of the 2007 Site Investigation and 2009 supplemental soil sampling in the drainage area (i.e., Northern Range Exposure Area) were included with the new RI data for evaluation in the RI Report. The RI results are summarized in Section 1.4–Nature and Extent of Contamination and Section 1.5–Conceptual Site Model and Contaminant Fate and Transport. Summaries of the risk assessments from the RI Report are presented in Section 1.6–Human Health Risk Assessment and Section 1.7–Ecological Risk

Assessment. Pertinent tables and figures from the RI and other historical information are provided in Appendix A–Historical Information.

Contaminant migration from soil to groundwater is not a pathway of concern at this site based on the soil and groundwater data collected during the 2007 Site Investigation (Tetra Tech, 2018a). Therefore, in accordance with the RI work plan, the RI fieldwork did not include groundwater sampling (Tetra Tech, 2009a, 2018a, and 2018b). However, the RI Report did reevaluate the migration potential using the Site Investigation groundwater data and the RI subsurface soil data. The RI Report concluded that lead and PAH migration from soil to groundwater is not a concern at this site (see Section 1.4.1.3).

1.3.4 Surface Features, Geology, and Hydrogeology

WFF is on the Eastern Shore of Virginia within the Atlantic Coastal Plain physiographic province. The regional geology is a series of layered, unconsolidated, sedimentary units deposited in the Salisbury Embayment (Meng and Harsh, 1988). The sediments comprise an eastward-thickening wedge that dips to the northeast toward the Atlantic Ocean. Near WFF, approximately 7,000 feet of sediment lie atop crystalline basement rock. The two stratigraphic groups encountered at WFF are the Chesapeake Group and the overlying Columbia Group.

The MBFR Complex is located on the northern side of the Main Base, east of Runway 17-35, on a peninsula-like feature adjacent to Little Mosquito Creek. The southern half and the central portion of the MBFR Complex, generally coinciding with the former Rifle and Pistol Ranges, is mostly grassy and flat, with little slope. The perimeter of the MBFR Complex consists of gentle slopes ranging from 1 to 4 percent to the northwest, north, and east. There are no streams within the MBFR Complex, and drainage is via overland sheet flow. Little Mosquito Creek is located about 400 feet north of the MBFR Complex. The southern and eastern downrange portions of the former east-facing skeet range drain into a centralized collection area where surface runoff is directed through a concrete drainage culvert to the Northern Range Exposure Area (Figure 1-2). The Northern Range Exposure Area consists of a drainage swale that discharges water from the drainage culvert to Little Mosquito Creek and associated wetlands (Figure 1-4). Vegetation on the northern and eastern portions of the site consists of conifers, bushes, and tall grasses (Tetra Tech, 2018c and 2020). These habitats are described as Old Field and Deciduous Scrub with woody plants exceeding 3 inches in diameter (Tetra Tech, 2009a and 2018c). The Old Field is highly heterogeneous grass and forb cover with patches of grasses such as tall fescue, Bermuda grass, and broomsedge bluestem and forbs such as prickly dewberry (*Rubus flagellaris*) and Japanese honeysuckle. Other forbs include wingstem (*Verbesina alternifolia*), blue mistflower (*Conoclinium coelestinum*), common dogbane (*Apocynum cannabinum*), poison ivy seedlings, upland boneset (*Eupatorium sessilifolium*), Allegheny blackberry (Rubus allegheniensis), grass-leaved goldenrod (*Euthamia graminifolia*), fall dandelion (*Leontodon autumnalis*), and small white aster (*Symphyotrichum racemosum*). The Deciduous Scrub is a dense scrub dominated by deciduous saplings and mature tress such as black cherry (*Prunus serotina*) and deciduous shrubs such as bush Honeysuckles. Other saplings and mature trees include loblolly pine (*Pinus taeda*), sweet gum (*Liquidambar styraciflua*), red maple, and tulip poplar (*Liriodendron tulipifera*). Other common shrubs include groundsel tree and winged sumac. Non-native invasive autumn olive saplings (*Elaeagnus umbellate*) are somewhat spread across the vegetated areas of the site.

A portion of the Northern Range Exposure Area is palustrine forested wetland. The National Wetland Inventories (NWI) describes it as a palustrine scrub-shrub, broad-leaved deciduous seasonally flooded-tidal wetland (US Fish and Wildlife Service [USFWS], 2012). The Tetra Tech (2018c) wetland delineation confirmed this and used observations of hydrology and absence of prominent hydrophytic vegetation to describe the area as upland changing to slope palustrine forested wetland dominated by red maple and black gum (*Nyssa sylvatica*) that seasonally tidally drains into Little Mosquito Creek. Herbaceous emergent vegetation exists in fractured communities through the wetland complex, dominated by Phragmites (*Phragmites australis*), jewelweed (*Impatiens capensis*), common rush (*Juncus effusus*), and common cattail.

The MBFR Complex area is undeveloped. The WFF Master Plan indicates that the area will remain undeveloped because of building height and occupancy restrictions. These restrictions are in place due to the proximity of the active facility runways, which are an essential component of the facility mission.

At WFF the surficial geology can be characterized as a silty fine-grained sand with varying amounts of clay and gravel. The soil types indicated in the Tetra Tech (2004) *Background Soil and Groundwater Investigation Report for the Main Base* are described for each of the exposure areas in Section 1.3.2. The thickness of this silty fine-grained sand varies, but it can be as thick as 15 feet or absent altogether. Below the silty fine-grained sand is a coarser well-sorted fine- to medium-grained sand. Most soil encountered at the Skeet Range MRS during the Site Investigation and RI was silty fine-grained sand with varying amounts of organics and trace amounts of medium- to coarse-grained sand.

The local aquifer system at WFF consists of the Upper, Middle, and Lower Yorktown-Eastover aquifers and the overlying unconfined Columbia Aquifer (also called the “surficial” aquifer). The Yorktown-Eastover Aquifers serve as the primary source of water for public and domestic supplies and for agricultural and industrial uses. The hydrogeologic framework is derived from *Hydrogeology and Analysis of the Ground-Water-Flow System of the Eastern Shore, Virginia* (Richardson, 1994).

The Columbia Group extends to a subsurface depth of approximately 60 feet and consists of interbedded sands, gravels, and sandy clays deposited under fluvial and marine conditions. The Columbia Group is overlain by a variably thin (generally about 5 feet) veneer of recent deposits composed chiefly of wind-deposited or fluvial sands, silts, and gravels. Within the Columbia Aquifer there are a series of clay, silt, and/or sandy clay lenses. These lenses are not contiguous and do not act as a confining layer, but they can impede vertical flow locally. The water table beneath the WFF typically occurs under unconfined conditions within the recent deposits and Columbia Group at depths of 0 to 30 feet (Occu-Health, 1999). Groundwater flow generally mimics topography (Tetra Tech, 2004 and 2009a) (see Appendix A).

1.3.5 Demography and Land Use

The MBFR Complex is in a secured industrial area adjacent to WFF’s active airfield and NOAA’s operational antennae towers. Access is very limited due to operations. There are no residences or offices in this area. Current land use is industrial, and the land use is expected to remain industrial in the future. Culturally sensitive areas exist in the vicinity of the Skeet Range MRS and the associated exposure areas (Figure 1-7). All exposure areas at the site overlap partially with cultural resources restricted areas. NASA will coordinate with the Virginia Department of Historic Resources (VDHR) and appropriate Native American tribes.

1.3.6 Ecology

The habitats at the MBFR Complex consist primarily of overgrown vegetation, including grasses, shrubs, and trees. The southern half of the Skeet Range MRS is mostly flat, with little slope. However, along the northern, eastern, and northwestern boundaries of the study area, steep slopes direct surface runoff into low-lying marshes that border Little Mosquito Creek. Approximately 300 to 500 feet of marshland separates Little Mosquito Creek from the MBFR Complex to the north and east. There are no surface water bodies within or immediately adjacent to the Complex; however, drainage from the Southern Range Exposure Area flows through a culvert into the northern portion of the site, including a palustrine forested wetland habitat situated in the downstream reaches of the Northern Range Exposure Area (Figures 1-2 and 1-4).

1.4 NATURE AND EXTENT OF CONTAMINATION

The summary discussion below is derived mainly from the RI Report (Tetra Tech, 2020). The results of the 2007 Site Investigation and 2009 supplemental soil sampling in the drainage area were included with the new RI data for evaluation in the RI Report. Contaminant migration from soil to groundwater is not a pathway of concern at this site based on (i) the soil and groundwater data collected during the Site Investigation and the RI and (ii) the conclusions of the RI Report (Tetra Tech, 2018a and 2020). PRGs were initially developed in the RI SAP (2018a) and RI Report (2020) to present and evaluate the data (see Table 1-1); the same approach is used herein to discuss the data. The PRG development and selection is described in Section 2.0 and shown in Table 2-1. Figure 1-3 through Figure 1-6 show historical sample locations with PRG exceedances indicated within each exposure area. Historical data tables and figures are provided in Appendix A.

1.4.1 General Summary

There are no known continuing sources of lead shot or PAHs at the site. Lead contamination in the soil at the site (including the soil/sediments in the Northern Range Exposure Area) is due to the leaching of lead from lead shot remaining in the soil. For the discussion of nature and extent of contamination and the CSM, surface soils are defined as being from the ground surface to 1 foot below ground surface (bgs).

Note that for the human health risk assessment (HHRA) (see Section 1.6) and ecological risk assessment (ERA) (see Section 1.7) conducted during the RI, surface soil was defined as 0 to 6 inches and subsurface soil as 6 to 24 inches bgs (see Figures 1-8 and 1-9). However, the ERA included the “shallow subsurface soil” depth of 6 to 12 inches bgs with the surface soil in its assessment. Soil samples collected from within and just upland of the palustrine forested wetland were evaluated as soil in the HHRA and as sediment in the ERA in the RI Report. For remedial alternative evaluation and discussion in this FS, surface soil is defined as the 0 to 1 foot bgs and subsurface soil is below 1 foot bgs (consistent with a practical, constructible 1-foot-lift/depth interval).

1.4.1.1 Surface Soil

Lead analysis was performed on 199 surface soil samples at the Skeet Range MRS cumulatively during the 2007 Site Investigation sampling, 2009 follow-up sampling in the drainage area, 2011 NOAA sampling, and the 2019 RI sampling. Lead shot counts were observed during the 2007 sampling and 2009 follow-up sampling (56 surface soil samples), as well as and during the RI (142 surface soil samples). Lead concentrations, lead shot counts, and total point risk from PAHs all exceeded their respective PRGs [developed initially during the RI] in surface soils. The highest lead concentrations were observed in surface soil (0 to 1 foot bgs) in the Northern Range Exposure Area, particularly near the low-lying drainage swale, and in the Southern Range Exposure Area. The highest lead shot counts were observed in the Southern Range Exposure Area and generally encompassed the same area as the samples with the highest lead concentrations. In the Skeet Range Shooting Exposure Area, total point carcinogenic risk values above 1×10^{-4} for PAHs were observed in the western portion of the area, near the former trap houses.

1.4.1.2 Subsurface Soil

Lead analysis was performed on 19 subsurface soil samples during the RI. The maximum lead concentrations in subsurface soil were: 140 mg/kg in the Northern, 191 mg/kg in the Southern, and 18.2 mg/kg in the High Tower Range Exposure Areas. The concentrations were less than both the human health and ecological PRGs initially developed during the RI. Most of the lead shot in both the High Tower and Southern Range Exposure Areas was found in the 0- to 6-inch and 6- to 12-inch depth intervals. However, some lead shot was found in the 1- to 2-foot depth interval in the Southern Range Exposure Area. The maximum lead shot counts in subsurface soil at the Southern Range Exposure Area is 45 LS/foot^2 at SR-SS-220 at 12 to 24 inches bgs, which is below the ecological PRG. PAH concentrations in subsurface soil within the Skeet Range Shooting Exposure Area are generally low and total point carcinogenic risk values do not exceed the acceptable limits.

1.4.1.3 Groundwater

Groundwater samples were collected during the 2007 Site Investigation. The groundwater results from two temporary wells (RRMW-02 and RRMW-03) in the subject Skeet Range MRS show lead concentrations at less than 2 micrograms per liter (µg/L) and no detections of PAHs. These lead groundwater concentrations are below screening levels and indicate that groundwater at the Skeet Range MRS has not been adversely impacted by lead from the former range activities. Therefore, the RPM Team agreed that no further investigation or action is warranted for groundwater at the site (Tetra Tech, 2009a, 2018a, and 2020; USACE, 2012).

1.4.2 High Tower Range Exposure Area

Samples collected in the High Tower Range Exposure Area were analyzed for lead and lead shot. The arithmetic mean lead concentration in surface soil is below the human health PRG of 200 mg/kg at 115 mg/kg in the 0- to 6-inch interval and 52 mg/kg in the 6- to 12-inch interval; however lead concentrations are above 200 mg/kg in surface soil samples at three locations: SR-SS-252, 254-, and -256 located northeast of the former High Tower Trap House (Figure 1-3). The maximum surface soil lead concentration is 508 mg/kg at SR-SS-254. The maximum and arithmetic mean lead concentrations in subsurface soil are 18.2 mg/kg and 10 mg/kg, respectively. Most lead shot was found in the 0- to 6-inch depth interval in the southeastern portion of the area; none was encountered in subsurface soil in this exposure area. The highest lead shot count is 359 LS/foot^2 in the 0- to 6-inch depth interval at SR-SS-256. Delineation of lead shot associated with the High Tower Range Exposure Area encroaches into the western portion of the Northern Range Exposure Area.

1.4.3 Northern Range Exposure Area

There is some uncertainty as to whether the low-lying soil/sediment samples at the Northern Range Exposure Area provide habitat for sediment invertebrates, so they are considered and were evaluated as sediment samples in the context of ecological assessment to be conservative. However, they were evaluated as surface soil for human health. Soil/sediment samples collected in the Northern Range Exposure Area were analyzed for lead. Delineation of lead shot from the High Tower Range Exposure Area encroaches into the Northern Range Exposure Area, but there are no lead shot observations specifically in this exposure area (Figure 1-4). The maximum lead concentration is 22,200 mg/kg in surface soil from location SR-SS-213 at the 0- to 6-inch depth interval. The arithmetic mean lead concentration in this exposure area is 1,112 mg/kg in the 0- to 6-inch depth interval, 185 mg/kg in the 6- to 12-inch depth interval, and 57 mg/kg in depth intervals deeper than 1 foot. Lead was detected in only three subsurface soil samples in this area. The highest lead concentrations in this exposure area were observed in samples collected in the low-lying areas of the drainage swale that conveys runoff from the east-facing skeet range to Little Mosquito Creek through the palustrine wetland.

1.4.4 Southern Range Exposure Area

The maximum lead surface soil concentration in the Southern Range Exposure Area is 1,140 mg/kg at SS-SR-235. The arithmetic mean lead surface soil concentrations in this exposure area are 196 mg/kg for the 0- to 6-inch interval and 86 mg/kg for the 6- to 12-inch interval. Most lead shot was found in the 0- to 6-inch interval on the flat grassy portions in the southern half of the area or along the NOAA fence line (Figure 1-5). The highest lead shot count is 967 LS/foot^2 in the 0- to 6-inch interval at location SR-SS-235. The samples with the highest lead shot counts generally encompass the same area as the samples with the highest lead concentrations. The maximum lead concentration in subsurface soil is 191 mg/kg and the arithmetic mean is 30 mg/kg. Lead shot was encountered in subsurface soil at 45 LS/foot^2 at SR-SS-220 in the 12- to 24-inch interval.

1.4.5 Skeet Range Shooting Exposure Area

The Skeet Range Shooting Exposure Area is encompassed by the Southern Range Exposure Area but is specific to PAH exposure concerns near the former firing line and shooting stations of the former east-facing skeet range. PAH analysis was performed on 84 surface soil samples during the 2007 Site Investigation, 2009 supplemental sampling, and 2018 to 2019 RI Sampling. Seven PAHs were identified as the target PAHs (i.e., risk drivers) and were screened using a calculated total point cancer risk value of 1×10^{-4}. Locations where the total point risk exceeds 1×10^{-4} are indicated on Figure 1-6. The highest total point risk in surface soil samples for PAHs was 7.1×10^{-4} in the 0 to 6-inch depth interval at location SR-SS-267. The majority of the risk is contributed by benzo(a)pyrene at 49 mg/kg and dibenzo(a,h)anthracene at 12,000 mg/kg at this location. PAH concentrations in subsurface soil are generally low, providing a maximum total point risk of 2.6×10^{-6} at location SR-SB-258 in the 12- to 24-inch depth interval.

1.5 CONCEPTUAL SITE MODEL AND CONTAMINANT TRANSPORT

A CSM facilitates consistent and comprehensive evaluation of potential risks to human health by creating a framework for identifying the pathways by which human receptors may contact environmental media contaminated by site activities. A CSM depicts the relationships among the following elements, which are necessary for defining complete exposure pathways:

- Site sources of contamination
- Contaminant release mechanisms and transport/migration pathways
- Exposure routes
- Potential receptors

The elements of the CSM establish the manner and degree to which a potential receptor may be exposed to COCs present at the site. The degree of risk incurred by a potential receptor varies according to the means, duration, and the specific chemical to which the receptor is exposed. An exposure, however long in duration, does not necessarily result in an “unacceptable” health or environmental risk, although risks generally increase with increased frequency and/or duration of exposure.

Section 1.3 summarizes the site background, features, physiography, history, and previous investigations. Current site usage is considered industrial and is anticipated to remain industrial in the future. No future residential uses are planned for this area. The site problem, based on this CSM, is best summarized as follows: The Skeet Range MRS was composed of multiple firing range configurations whose activities resulted in soil and sediment contamination of lead from lead shot and PAHs from clay pigeons. The lead shot fragments are also of concern because they are similar in size to the grit ingested by certain bird species and, thus, pose an ecological risk. The skeet ranges are no longer active.

Once contaminants are released to an environmental medium (e.g., soil), they can migrate within that medium or migrate to another environmental medium (e.g., groundwater). Contaminants in surface soil and subsurface soil could migrate to surrounding groundwater through leaching of chemicals in the soil. The groundwater underlying the site is primarily recharged through infiltration of precipitation and subsurface flow from upgradient/adjacent areas. This allows for migration of contaminants downward through the soil column to the shallow groundwater. However, soil and groundwater data (metals and PAHs) from the Site Investigation for the whole MBFR Complex indicate that shallow groundwater has not been adversely impacted by metals and PAHs from the site. This was reaffirmed in the RI Report.

Lead concentrations, lead shot counts, and total point risk from PAHs all exceed their respective PRGs in surface soils (see Section 2.3). The highest lead concentrations are in surface soil (0 to 1 foot bgs) in the Northern Range Exposure Area, particularly near the low-lying drainage swale, and in the Southern Range Exposure Area. The highest lead shot counts are in the Southern Range Exposure Area and generally encompass the same area as the samples with the highest lead concentrations. In the Skeet Range Shooting Exposure Area, total point risk values above 1×10^{-4} for PAHs are in the western portion of the area near the former trap houses and firing lines.

1.6 HUMAN HEALTH RISK ASSESSMENT

The Tetra Tech (2009a) Site Investigation Report included a human health risk evaluation where the 2007 data were compared to EPA risk-based screening values followed by risk ratio calculations. The evaluation concluded no unacceptable risk for industrial workers and potential future residents exposed to lead in surface soil based on the site-wide average (prior to the use of exposure areas in the RI Report); however, several individual concentrations were elevated. The unacceptable risk for potential future residents was cancer risk from PAHs near the former trap houses and firing lines of the former east-facing skeet range.

The RI Report included a reevaluation of human health risks using additional data for exposure to lead and PAHs in surface and subsurface soil; the reevaluation also included breaking the site into exposure areas for more accurate risk characterization (Tetra Tech, 2020). No other medium presents a complete exposure pathway (see Section 1.3.3). Potential risks were identified during the RI again in both surface and subsurface soil for lead and in surface soil for PAHs. The exposure pathway analysis from the HHRA in the RI Report is presented as Figure 1-8. The HHRA defined surface soil as 0 to 6 inches bgs and subsurface soil as 6 inches to 24 inches bgs. Like the evaluation in the Site Investigation Report, the HHRA in the RI Reports screened site data against USEPA risk-based screening values to identify Chemicals of Potential Concern (COPCs). Next, cancer and non-cancer risk estimates were developed based on ratios of COPC exposure point concentrations (EPCs) to the USEPA screening values (i.e., RSLs) for residential and industrial soil exposures). An unacceptable risk was determined under Reasonable Maximum Exposure (RME) conditions when (a) the individual or cumulative Incremental Lifetime Cancer Risk (ILCR) exceeded 1×10^{-4} or (b) the target organ- or critical effect-specific Hazard Index (HI) exceeded unity (1). In addition, potential child and adult lead risks were evaluated by means of modeling blood lead levels affected by soil exposure following USEPA guidance and using a goal of no more than 5 percent of receptors with a blood level exceeding 5 micrograms per deciliter (µg/dL). COPCs with calculated risks exceeding the respective risk thresholds are the human health COCs addressed in this FS (Table 1-2): Lead and seven

PAHs (benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene). The CERCLA COCs are discussed further in Section 2.3.

The only human health COPC identified in surface and subsurface soil in the High Tower and Northern Range Exposure Areas was lead. Therefore, cancer risks and HIs were not calculated for these two exposure areas. Estimated risks for COPCs in surface soil and subsurface soil at the Southern Range Exposure Area and overlapping Skeet Range Shooting Exposure Area are presented in Table 1-3 (residential) and Table 1-4 (industrial) and are summarized below. Cancer risks are associated with each of the seven PAHs; non-cancer risks are associated with benzo(a)pyrene only.

Risk Summary Southern and Skeet Range Shooting Exposure Areas

Area	Hazard Index		Cancer Risk	
	Residential	Industrial	Residential	Industrial
Surface Soil	0.5	0.04	2×10^{-4}	8×10^{-6}
Subsurface Soil	0.5	0.04	1×10^{-4}	7×10^{-6}

HIs for residents and industrial workers exposed to surface soil and subsurface soil at the Southern Range Exposure Area (and overlapping Skeet Range Shooting Exposure Area) are less than the threshold level of 1. Cancer risks for residents exposed to PAHs in surface soil exceed USEPA's target risk range of 1×10^{-4} to 1×10^{-6}, while cancer risks for residents exposed to subsurface soil are equal to the upper bound of the target risk range (1×10^{-4}). Cancer risks for industrial workers exposed to surface soil and subsurface soil are within USEPA's target risk ranges.

Lead was identified as a human health COPC in surface soil at the High Tower Range Exposure Area, surface and subsurface soil at the Northern Range Exposure Area, and surface and subsurface soil at the Southern Range Exposure Area. Concentrations of lead in subsurface soil at the High Tower Range Exposure Area are less than 200 mg/kg based on an acceptable blood lead level of 5 µg/dL. The Integrated Exposure Uptake Biokinetic (IEUBK) Model outputs from the RI Report are summarized below (USEPA, 2017b).

IEUBK Residential Lead Risk Summary

Exposure Unit	EPC (mg/kg)	Blood Lead Geometric Mean Concentration (µg/dL)	Percent of Receptors Exceeding 5 µg/dL
High Tower Range Exposure Area			
Surface Soil	117	2.05	2.88
Northern Range Exposure Area			
Surface Soil	1,107	10.3	93.8
Subsurface Soil	170	2.58	7.95
Southern Range Exposure Area			
Surface Soil	190	2.78	10.5
Subsurface Soil	84.2	1.71	1.13

The results for child residents exposed to lead in surface and subsurface soil at the Northern Range Exposure Area and surface soil at the Southern Range Exposure Area exceed the goal of less than 5 percent of children exceeding a 5-µg/dL blood lead level. The results for child residents exposed to lead in subsurface soil at the Southern Range Exposure Area and surface soil at the High Tower Range Exposure Area do not exceed the goal. Of note, the soil samples driving the lead risk in subsurface soil in the Northern Range Exposure Area are from the 6- to 12-inch depth interval. Lead concentrations from samples deeper than 1 foot are less than 200 mg/kg throughout the entire Skeet Range MRS.

Exposures to lead in surface soil and subsurface soil by industrial workers were evaluated using Adult Lead Methodology (ALM) model developed by USEPA's Technical Review Workgroup for Lead (2003 and 2017a). As recommended in the ALM documentation, the average lead concentrations in surface soil and subsurface soil in each respective exposure area were used as the EPCs. The fetus of a pregnant worker is the ultimate receptor of concern for the ALM model. The results of the ALM modeling from the RI Report are summarized below.

ALM Industrial Lead Risk Summary

Exposure Unit	EPC (mg/kg)	Blood Lead Geometric Mean Concentration (µg/dL)	Percent of Receptors Exceeding 5 µg/dL
High Tower Range Exposure Area			
Surface Soil	117	0.9	0.12
Northern Range Exposure Area			
Surface Soil	1,107	2.2	5.70
Subsurface Soil	170	0.8	0.07
Southern Range Exposure Area			
Surface Soil	190	0.9	0.08
Subsurface Soil	84.2	0.7	0.03

The results for industrial workers exposed to lead in surface soil at the Northern Range Exposure Area exceed the goal of less than 5 percent of fetuses of exposed women exceeding a 5-µg/dL blood lead level. The results for industrial workers exposed to lead in subsurface soil at the Northern Range Exposure Area, surface and subsurface soil at the Southern Range Exposure Area, and surface soil at the High Tower Range Exposure Area do not exceed the goal.

1.7 ECOLOGICAL RISK ASSESSMENT

A preliminary ecological risk screening evaluation in the Tetra Tech (2009a) Site Investigation Report evaluated the potential risks to terrestrial plants, invertebrates, and small mammals and birds exposed to soil, lead shot, and clay pigeons at the MBFR Complex using data collected in 2007. The soil and sediment in the Northern Range Exposure Area was not recognized as part of the site at that time. Several metals and PAHs throughout the site were identified as ecological COPCs due to screening level exceedances. After refinement of the conservative exposure assumptions and concentrations, preliminary food chain modeling, and consideration of background conditions, the evaluation concluded that lead concentrations in soil present a risk to plants and birds. In addition, the evaluation concluded that birds were at risk from potential ingestion of lead shot in the Southern Range Exposure Area. Additional investigation of lead concentrations and lead shot density was recommended.

The ERA in the RI Report reevaluated the ecological risk in surface and subsurface soil using more sample data and observations (Tetra Tech, 2020). The reevaluation effort was more informed by the 2009 supplemental sampling effort in the drainage area (Northern Range Exposure Area) and the USACE (2010) SI that identified historical skeet shooting activities conducted at the High Tower Range and east-facing skeet range. The Site Investigation data from 2007, supplemental investigation data from 2009, and the RI data from 2018 through 2019 were combined for evaluation in the ERA in the RI Report. Some “soil” samples collected in the Northern Range Exposure Area (drainage area and wetland) were evaluated as “sediment” in the ERA. The ERA in the RI Report consisted of Steps 1, 2, and 3a of the eight-step ERA process.

The ecological receptors evaluated in the RI Report were terrestrial plants, soil invertebrates, sediment invertebrates, insectivorous birds and mammals, and herbivorous birds and mammals. Figure 1-9 shows the ecological risk exposure pathway analysis for the site. Plants and soil invertebrates are directly exposed to chemicals in surface soil throughout the site, while sediment invertebrates are directly exposed to chemicals in sediment within the drainage channel in the Northern Range Exposure Area. Birds and mammals can be indirectly exposed to chemicals through feeding on plants/organisms that have accumulated chemicals from the soil. They can also be directly exposed to the chemicals through incidental ingestion of soil while feeding. Birds may incidentally ingest lead shot while searching for grit that are approximately the same size as or smaller than lead shot.

Continuing from the preliminary ecological risk evaluation in Tetra Tech (2009a) Site Investigation Report, the ERA in the RI Report considered the primary sources of contamination for ecological receptors to be lead shot (lead) and clay pigeon fragments (PAHs) in surficial soils. The lead from the lead shot can dissolve and enter the soil and the clay pigeons can break down and release PAHs to the soil (or PAH-bound clay fragments mixed with the soil). Clay pigeon fragments are very resilient and generally break down slowly over time. Deposition of lead shot and clay pigeons was initially on the surface (0 to 6 inches); however, some contamination may have moved into deeper soils (6 to 24 inches) through reworking of soil whether mechanically (e.g., construction) or naturally (e.g., earthworms). The site contains dense vegetation and grassy fields, which limit sheet flow of rainwater, allow for better infiltration of precipitation, and provide evapotranspiration. The northern drainage channel is recognized as the primary pathway for surface water runoff from the east-facing skeet range. This runoff eventually discharges to Little Mosquito Creek located north of the site.

Surface soil data (0 to 6 inches) and subsurface soil data (6 to 12 inches and 12 to 24 inches) were evaluated in each of the exposure areas. Surface soil/sediment samples within the northern low-lying areas and wetland leading out of the Northern Range Exposure Area were evaluated as sediment. Deeper soil/sediment samples (6 to 12 inches and 12 to 24 inches) were not evaluated as sediment, because the primary exposure location for sediment invertebrates would be further downstream if the surficial soil/sediment migrates to that area. It is not expected that the deeper soil/sediment will migrate downstream.

Based on the initial screening of the chemical data in the ERA, lead and several PAHs were initially selected as ecological COPCs in soil and sediment because they were detected at concentrations above conservative screening levels, they had ecological effects quotients (EEQs) greater than 1.0 in the conservative food chain models, or because they did not have screening levels. The EEQ approach was used to characterize risk by comparing exposure concentrations with effects data. Lead and PAHs were further evaluated in the Tier 2, Step 3a process to refine the list of ecological COPCs and to better characterize risks to ecological receptors. PAHs were eliminated as COPCs for all ecological receptors in all areas based on spatial extent, limited bioavailability (PAHs bound to the clay pigeon fragments), food chain modeling results, and comparison to literature toxicity values and studies for PAHs. Lead in surface soil and sediment was retained as a COC for risks to the following ecological receptors in the following exposure areas:

- Terrestrial plants in the Northern and Southern Range Exposure Areas. (Lead was eliminated as a COPC for plants in the High Tower Range Exposure Area).

- Soil invertebrates in the southeastern portion of the Northern Range Exposure Area.

- Sediment invertebrates in the low-lying (wetland) portion of the Northern Range Exposure Area.

- Insectivorous birds in the Northern Range Exposure Area.

Lead shot was also retained as an ecological "COC" in surface soil in the High Tower and Southern Range Exposure Areas. Lead shot was not observed in the Northern Range Exposure Area. Lead shot ingestion probability modeling was performed using the lead shot and soil sieve results with Bennett et al.'s (2011) model recommended by EPA. Table 1-5 summarizes the ingestion probability for each sample where lead shot was collected within the Southern Range and High Tower Range Exposure Areas using a No.10 sieve (2 millimeter [mm]), No. 14 sieve (1.4 mm), and No. 20 sieve (0.84 mm). Most lead shot were retained on the No. 10 sieve and a few lead shot were retained on the No. 14 sieve; no lead shot made it through to the No. 20 sieve. Because the habitat at the site where lead shot was observed is not a wildlife refuge or other type of sensitive environment, a probability of 20 percent that a bird would ingest one lead shot was the basis of the recommended lead shot PRG developed during the RI (Tetra Tech, 2018a). This probability level was used to determine unacceptable risks to birds in the ERA during the RI.

The probability models are included in Appendix I of the RI Report. The probability modeling was conducted for all three ecological depth intervals (0- to 6-inch, 6- to 12-inch, and 12- to 24-inch), although the primary lead shot exposure for birds would be in the top 6 inches. Generally, higher numbers of lead shot were found in the 0- to 6-inch depth interval. Referring to Table 1-5, with one exception (94 LS/foot^2 in sample SR-SS-407-0006), the probability of ingesting lead shot was less than 20 percent when 100 or fewer lead shot were present in a sample (normalized to an area of 1 foot^2) based on non-lead particles retained on the No. 14 sieve. When based on non-lead particles retained on the No. 20 sieve, the probability of ingesting lead shot was less than 3 percent.

2.0 DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES

This section presents pertinent information for development and evaluation of remedial alternatives. Specific goals of this section are as follows:

- Identify federal and state ARARs (Section 2.2).
- Identify the media of concern and COCs (Section 2.3).
- Develop PRGs (Section 2.4).
- Determine RAOs to guide development of remedial alternatives (Section 2.5)
- Define the areas and volumes of the media to be addressed (Section 2.6).

2.1 NCP REQUIREMENTS

The NCP requires that the selected remedy meet the following objectives:

- Each remedial action selected shall be protective of human health and the environment.

- On-site remedial actions that are selected must attain those ARARs that are identified at the time of the ROD signature.

- Each remedial action selected shall be cost-effective, provided that it first satisfies the threshold criteria. A remedy shall be cost-effective if its costs are proportional to its overall effectiveness.

- Each remedial action shall use permanent solutions and alternative treatment technologies or resource-recovery technology to the maximum extent practicable.

The statutory scope of CERCLA was amended to include the following general objectives for remedial action at all CERCLA sites:

- Remedial actions "…shall attain a degree of cleanup of hazardous substances, pollutants, and contaminants released into the environment and of control of further releases at a minimum which assures protection of human health and the environment".

- Remedial actions "…in which treatment that permanently and significantly reduces the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants is a principal element" are preferred. If the treatment or recovery technologies selected are not a permanent solution, an explanation must be published.

- The least-favored remedial actions are those that include "off-site transport and disposal of hazardous substances or contaminated materials without treatment where practicable treatment technologies are available".

- The selected remedy must comply with or attain the level of any "standard, requirement, criteria, or limitation under any federal environmental law or any promulgated standard, requirement, criteria, or limitation under a state environmental or facility siting law that is more stringent than any federal standard, requirement, criteria, or limitation".

2.2 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

As required by Section 121 of CERCLA, remedial actions carried out under Section 104 or secured under Section 106 by the President must attain the levels of standards of control for hazardous substances, pollutants, or contaminants specified by the ARARs of federal and state environmental laws and state facility-siting laws, unless waivers are obtained. Only promulgated federal and state laws and regulations can be considered ARARs. If the ARARs are neither applicable nor relevant and appropriate, then the federal lead agency's remedial actions may be based on the "to be considered (TBC)" criteria or guidelines. These distinctions are critical to understanding how the federal lead agency integrates environmental requirements from other federal and state laws into its cleanup decision. The definitions of ARARs and TBCs below are from the NCP (40 CFR 300.5) and USEPA (1991).

- **Applicable requirements** are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

- **Relevant and appropriate requirements** are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable," address problems or situations sufficiently similar (relevant) to those encountered at a CERCLA site, that their use is well-suited (appropriate) to the particular site.

- **TBC** information are non-promulgated criteria, advisories, guidance, and proposed standards that have been issued by the federal or state government that are not legally binding and do not have the status of potential ARARs. However, the TBC information may be useful for developing an interim remedial action or for determining the necessary level of cleanup for the protection of human health and/or the environment. Examples of TBC information include USEPA Drinking Water Health Advisories, Reference Doses (RfDs), and Cancer Slope Factors (CSFs).

Another factor in determining which response or remedial requirements must be met is whether the requirement is substantive or administrative. CERCLA response actions must meet substantive requirements but not administrative requirements. Substantive requirements are those dealing directly with actions or with conditions in the environment. Administrative requirements implement the substantive requirements by prescribing procedures such as fees, permitting, and inspection that make substantive requirements effective. This distinction applies to on-site actions only.

The remedial action alternatives developed in this FS report are analyzed for compliance with federal and state ARARs. The analysis involves identifying requirements for each of the alternatives, evaluating their applicability or relevance, and determining if the alternatives can achieve the ARARs. Alternative-specific ARAR evaluations are provided in Section 4.0. Tables 4-2 through 4-4 summarize the ARARs and TBCs by classification with respect to the remedial alternatives evaluated in Section 4.0: Chemical-, location-, and action-specific.

- **Chemical-Specific**–Health- or risk-based numerical values or methodologies that establish cleanup levels for particular contaminants.

- **Location-Specific**–Requirements that restrict remedial actions based on the characteristics of the site or its immediate environs.

- **Action-Specific**–Requirements that set controls or restrictions on the design, implementation, and performance levels (including discharge limits) of activities related to the management of hazardous substances, pollutants, or contaminants.

Any remedial action at the site must meet standards as defined by the federal and state ARARs unless waived by the federal lead agency. If the ARARs do not address a particular situation, then remedial actions may be based on the TBC criteria or guidelines. Standards developed using TBCs are not enforceable unless and until incorporated into the ROD.

2.3 MEDIA AND CHEMICALS OF CONCERN

Soil alternatives were developed assuming maintained future/industrial land use. As discussed in Section 1.6–Human Health Risk Assessment and Section 1.7–Ecological Risk Assessment, risks were evaluated and quantified for each exposure area during the RI. The HHRA determined unacceptable cancer risk (i.e., ILCR greater than 1×10^{-4}) for exposure to PAHs in surface soil (i.e., 0- to 6-inch and 6- to 12-inch depth intervals) at the Skeet Range Shooting Exposure Area (Figure 2-1). The HHRA also determined unacceptable non-cancer risks from exposure to lead in surface and shallow subsurface soils in the Northern Range Exposure Area and in surface soil in the Southern Range Exposure Area. No unacceptable human health risks were determined from exposure to soil deeper than 1 foot. The ERA determined unacceptable risk to terrestrial plants, soil invertebrates, and insectivorous birds exposed to lead in surface soil the Northern Range Exposure Area, sediment invertebrates to lead in sediment in the Northern Range Exposure Area, and terrestrial plants to lead in surface soil in the Southern Range Exposure Area (Figure 2-1). The ERA also determined unacceptable risk to birds from lead shot in surficial soils (0- to 6- and 6- to 12-inch depth intervals) in the High Tower and Southern Range Exposure Areas (Figure 2-1). No unacceptable ecological risks were determined from exposure to soil or sediment deeper than 1 foot.

2.3.1 Media of Concern

Surface soil is generally considered to be 0 to 1 foot bgs. For the remainder of the FS, surface soil will refer to the 0- to 1-foot soil interval; this will address surface (0 to 6 inches) and "shallow subsurface" (6 to 12 inches) soils discussed in the risk assessments. Subsurface soil is unsaturated soil deeper than 1 foot; no unacceptable risks were determined for human health or ecological receptors exposed to soil deeper than 1 foot. Unacceptable human health risks were concluded in the RI Report for residential and industrial exposure to lead in surface soil and residential exposure to PAHs in surface soil. Unacceptable ecological risks were concluded in the RI Report for terrestrial plant, soil invertebrates, and birds exposed to lead in surface soil, as well as for sediment invertebrates exposed to lead in the sediment. The ERA also determined unacceptable risk to birds from ingestion of lead shot in surface soil. Therefore, both surface and shallow subsurface soil will be addressed as media of concern in this FS—collectively as surface soil from 0 to 1 foot (Table 1-2). For purposes of the FS, the sediment in the drainage area of the Northern Exposure Area is generally referred to as soil/sediment.

2.3.2 Chemicals of Concern

There are no COCs for groundwater or surface water. Lead and seven PAHs are identified as COCs in surface and subsurface soil (Table 1-2). Lead shot is identified as a COC in surface soil (Table 1-2). These are the COCs for which soil PRGs are developed in this FS (Table 1-1, Table 2-1, and Section 2.4).

2.4 DEVELOPMENT OF PRELIMINARY REMEDIATION GOALS

PRGs are medium-specific contaminant concentrations that are protective of human health and/or the environment given the possibility of exposures to human or ecological receptors. PRGs can be risk-based—that is, based on site-specific assumptions of receptor activity patterns and cumulative toxicity for the mixture of chemicals present at a site. Alternatively, PRGs may be based on ARARs, which are chemical-specific regulatory standards for protectiveness that consider protection of human health or ecological concerns in a generic manner across various settings. PRGs are developed for the site as target cleanup goals for remedial actions that would reduce COC concentrations in site media of concern, and thereby mitigate risks to human health and the environment. In this section, PRGs are selected for COCs for surface soil and subsurface soil for each of human health and ecological receptors using the following steps.

PRG candidates were initially developed in the RI SAP (2018a) and RI Report (2020) to present and evaluate the data (see Table 1-1). These are included in the PRG selection process as shown in Table 2-1. PRGs can be derived through identification of chemical-specific ARARs. In this case, there are not any ARARs applicable to lead, PAHs, or lead shot in soil or sediment. When this is the case, TBCs are evaluated for use as, or development of, PRGs. Human health risk-based PRGs are developed by calculation of an acceptable risk using TBCs (e.g., toxicity reference values or lead modeling) to back calculate for each medium and COC. PRGs are considered for all media of concern and all exposure scenarios with unacceptable risks for both current and, in this case, hypothetical future land use scenarios. Although the site is not currently residential and there are no plans for residential use of the property in the future, PRGs for residential exposures to soil are calculated and presented for decision-making purposes.

For ecological risk-based PRGs, peer reviewed literature value TBCs are used to determine candidate PRGs. Lead probability models were used to determine the ecological lead shot PRG. These processes were done initially in the RI SAP (2018a) and RI Report (2020) to present and evaluate the data (see Table 1-1). Finally, PRGs are adjusted so that they do not exceed applicable background conditions; this provides assurance that remedial action goals are reasonably attainable and measurable. In this case, background values are below the proposed PRGs (see Table 2-1). Other risk management evaluations are also considered as appropriate to assure a PRG is not selected that either cannot be achieved or is not appropriate for the site and its conditions.

Table 2-1 presents the candidate and selected PRGs for COCs by receptor in soil and soil/sediment. Soil sample locations with lead concentrations, lead shot counts, or PAH-related ILCRs greater than the PRGs are indicated on Figures 1-3 through 1-6. Individual human health lead soil exceedances are indicated on each figure for reference and to evaluate potential hot spots; however, the HHRA evaluated lead based on the average concentration in each respective exposure area (i.e., unacceptable lead risks to human health were determined for each exposure area as a whole). These PRGs remain “preliminary” through the planning stages and risk management steps until the ROD is finalized, at which time they become established cleanup levels.

2.5 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

RAOs are medium-specific goals for protecting human health and the environment. The RAOs are typically based on the media and COCs, exposure pathways, current and potential future receptors, and acceptable contaminant levels or range of levels for each exposure pathway. Additionally, RAOs are developed to ensure compliance with ARARs. The RAOs for the Skeet Range MRS are as follows:

- Reduce unacceptable risks due to the residential and industrial exposure to lead and PAHs in soil above the cleanup levels.

- Reduce unacceptable risks to ecological receptors from exposure to lead in soil and sediment above the cleanup levels.

- Reduce unacceptable risks to ecological receptors from exposure to lead shot in soil above the cleanup level.

- Reduce migration of lead from upland soil to sediment in Little Mosquito Creek at levels that cause unacceptable risk to the environment.

2.6 ESTIMATION OF AREAS AND VOLUMES

For the development of remedial alternatives, areas and volumes of soil to which General Response Actions (GRAs) might be applied were determined, taking into account not only acceptable exposure levels (e.g., PRGs), but also site conditions and the nature and extent of contamination. Although NASA intends to maintain industrial site usage, the soil and sediment areas to be addressed are established to evaluate alternative(s) also protective of hypothetical future residential use (i.e., that will provide for unlimited use and unrestricted exposure [UU/UE]). The HHRA and ERA determined unacceptable risks in each exposure area as follows and as shown on Figure 2-1 (surface soil and sediment refer to a 0- to 1-foot depth interval):

- High Tower Range Exposure Area:
  - Ecological (mourning dove) exposure to lead shot in surface soil

- Northern Range Exposure Area:
  - Human (residential) exposure to lead in surface soil
  - Human (industrial) exposure to lead in surface soil
  - Ecological (worms, rye grass, and mourning dove) exposure to lead in surface soil
  - Ecological (benthic invertebrates) exposure to lead in sediment

- Southern Range Exposure Area:
  - Human (residential) exposure to lead in surface soil
  - Ecological (rye grass) exposure to lead in surface soil
  - Ecological (mourning dove) exposure lead shot in surface soil

- Skeet Range Shooting Exposure Area:
  - Human (residential) exposure to PAHs in surface soil

Individual PRG exceedances are shown by location on Figures 1-3 through 1-6. Note that while the individual lead exceedances are indicated on the figures, the human health and ecological risk calculations use the average lead concentration as the EPC in the respective exposure area. Addressing lead in soil at the more conservative human health average-PRG of 200 mg/kg will also address the ecological lead soil risks (see Table 2-1). The areas of surface soil to be addressed by remedial action due to unacceptable risk and respective PRG exceedances are shown on Figure 2-2. These areas are the Areas of Attainment

(AAs) for soil comprising several 1-foot-deep target remediation zones (TRZs) based on the COC and location to be addressed. Referring to Figure 2-2–Soil Attainment Areas, the estimated size of each TRZ and the total volume to be addressed are summarized below (also see Appendix B–Quantity Calculations). Each TRZ is an AA or portion of the overall AA. The raw total must be adjusted by removing the overlap areas for the total area(s) and volume(s) to be accurately reflected for, e.g., an excavation remedial action.

Exposure Area	**AA/TRZ**	**Media**	**Size (acre)**	**Depth (feet)**	**Volume (BCY)**
Northern Range	L1	Soil	0.59	1	948
Northern Range	L1 Sediment	Sediment	0.04	1	63
High Tower Range	LS1	Soil	0.85	1	1,370
Southern Range	L2	Soil	1.63	1	2,630
Southern Range	LS2	Soil	1.74	1	2,804
Southern Range	LS3	Soil	0.06	1	104
Southern Range / Skeet Range Shooting Area	PAH1	Soil	0.19	1	311
Southern Range	PAH2	Soil	0.02	1	29
Southern Range / Skeet Range Shooting Area	PAH3	Soil	0.11	1	178
Overlaps					
Northern Range	*L1 Sediment*	*Sediment*	*0.04*	*1*	*63*
Northern Range	*L1/LS1 overlap*	*Soil*	*0.18*	*1*	*289*
Southern Range	*L2/LS2 overlap*	*Soil*	*1.36*	*1*	*2,200*
Total (overlaps removed)			**3.65**	**1**	**5,884**

BCY - Bank cubic yards (in situ volume of soil prior to any digging or handling)

The AA for PAH soil comprises three relatively small TRZs (PAH1, PAH2, and PAH3). The AA for lead shot comprises two large TRZs (LS1 and LS2) and one small TRZ (LS3) in between. The AA for lead soil comprises two large TRZs (L1 and L2); TRZ L2 Sediment is a 63-BCY sediment portion within the L1 lead soil total in the Northern Range Exposure Area. Figure 2-2 shows the respective overlap areas of the large lead soil and lead shot TRZs. Considering the overlaps, the total area of the soil AA(s) is 3.65 acres. The area to be disturbed during remedial construction will be larger (see Section 4.0 and Appendix B).

The volume of soils to be addressed for protection of human health against risk to exposure from PAHs is approximately 520 BCY. The total volume of soil/sediment to be addressed for protection of human health and ecological receptors against risks from exposure to lead and lead shot—removing overlap areas/volumes—is approximately 5,370 BCY. Therefore, the grand total volume of soil/sediment to be addressed by remedial action is approximately 5,890 BCY (approximately 65 BCY of which is sediment from the palustrine forested wetland area in the Northern Range Exposure Area).

3.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section presents the identification and screening of remedial technologies and process options that may be potentially applicable to meet the RAOs for the site. The process starts with identifying and screening GRAs available to meet RAOs. Applicable remedial technologies and process options that can be used to implement the response actions are then identified, screened, and eventually combined to form remedial alternatives for the soils at the Skeet Range MRS. The description of the remedial alternatives and a detailed evaluation of these remedial alternatives are provided in Section 4.0.

Technology identification and screening are important preliminary steps in developing remedial alternatives. In this phase of the FS, potentially applicable technology types and process options are identified. The technologies and process options are then screened by evaluating each with respect to technical implementability, thereby reducing the number of options for further consideration. The technologies and process options considered implementable are then evaluated in greater detail. Technologies and process options retained through this evaluation are subsequently developed into remedial alternatives.

The steps for completing the identification, screening, and evaluation of technology types and process options are summarized below:

- Develop GRAs that will satisfy the RAOs
- Identify and screen representative remedial technologies and process options for each GRA
- Evaluate and select representative technologies and process options
- Assemble remedial alternatives from retained technologies and process options
- Screening of remedial alternatives for detailed evaluation

3.1 GENERAL RESPONSE ACTIONS AND TECHNOLOGY EVALUATION

GRAs presented in USEPA (1988) were evaluated for their applicability to site-specific conditions, environmental media, the nature of the contaminants, and how the potential risks would be mitigated. GRAs were selected based on the RAOs and the types and extent of contaminants present at the site. In developing remedial alternatives, combinations of GRAs may be identified to fully address all RAOs. GRAs identified as applicable for remediating soil/sediment include the following. A description of each GRA is provided below.

- No Action
- Limited Action
- Containment
- Removal
- Treatment
- Disposal

3.1.1 No Action

Under the no-action option, the affected media is left "as-is," without implementing any remedial technologies. This option does not provide for monitoring or placing access restrictions on contaminated media. Although this option requires no remedial action, it provides a baseline against which other GRAs can be evaluated.

3.1.2 Limited Action

This GRA includes Land Use Controls (LUCs) and monitoring. Normally, LUCs include institutional controls (ICs) and access restrictions that may limit use or access to the media to reduce or eliminate risk of exposure of receptors to hazardous materials. Access restriction measures may include physical barriers such as fencing, and/or signage to discourage access to the contaminated media. Typically, LUCs require regular follow-up inspections to verify their continued maintenance until cleanup goals have been reached. A long-term monitoring (LTM) program to ensure compliance and to assess changes in environmental conditions or changes because of, e.g., erosion or natural attenuation, can be part of this GRA. While ICs and physical barriers alone do not reduce the toxicity, mobility, or volume of contaminated media through direct means, naturally occurring processes may reduce contaminant concentrations over an extended period. Data generated from LTM activities would provide information to assist in determining the rate of contaminant concentration reductions through these naturally occurring processes, as well as the potential migration of COCs. Monitoring would also provide information on which to base a decision regarding the need to implement additional remedial actions, should migration be observed.

3.1.3 Containment

Containment technologies reduce potential exposure risks through the application of physical means. Physical barriers help to prevent direct contact with contaminated media and control potential erosion or migration. Barriers may consist of permeable covers or low permeability caps and may be comprised of natural or synthetic materials. Containment also can be used to reduce the movement of the contaminated media by preventing erosion of materials and restricting surface water movement through the contaminated media that may cause contaminant transport and leaching.

3.1.4 Removal

Removal technologies are used to collect contaminated media from their present locations and move them for subsequent disposal. For soil and sediment, removal is typically performed by excavation equipment, such as excavators and backhoes. Removal reduces the volume of contaminated media remaining on-site and allows site conditions to attenuate more rapidly than they would, had the contaminated media removal not occurred.

3.1.5 Treatment

Treatment technologies can be implemented in situ or ex situ. In situ treatment technologies treat the contaminated media in place by reducing the contaminants' toxicity, mobility, or volume. In situ treatment technologies are not always combined with other GRAs. Ex situ treatment technologies treat the contaminated media after that media has been removed from its current location. Ex situ treatment technologies are combined with removal and often disposal options. Ex situ processes may further include both on- and off-site options. Treatment technologies reduce contaminant volume, mobility, and/or toxicity. Treatment options include technology types and process options using thermal, physical, chemical, and/or biological means.

3.1.6 Disposal

Disposal technologies are combined with removal and/or treatment technologies to develop alternatives to clean up contaminated media at the site. Depending on the nature of the contaminated media, disposal may include the following options: Disposal at an off-site RCRA Subtitle C (hazardous) or Subtitle D (nonhazardous) landfill or treatment, storage, and disposal (TSD) facility; or disposal on land at a designated location at the facility. Disposal in a properly secured and maintained manner reduces the movement of the contaminated media.

3.2 SCREENING OF TECHNOLOGIES

Brief descriptions of preliminary screening, representative process options, and the detailed evaluation of technologies and process options retained in the preliminary screening are presented below.

3.2.1 Preliminary Screening

For the remediation of COCs in the media of concern, a variety of technologies and process options are available for each of the GRAs described in Section 3.1. A range of these technology types and process options was identified and screened to focus on relevancy. Summaries of the identification and preliminary screening of remedial technologies and process options appropriate for soil and sediment are provided in Table 3-1. Many options were eliminated based on the technology screening.

3.2.2 Representative Process Options

USEPA (1988) guidance for conducting the FS recommends that one representative process option be selected for each GRA to simplify the subsequent development and evaluation of alternatives without limiting flexibility during remedy selection or remedial design (RD). Representative process options are selected from the technologies remaining after preliminary screening based on effectiveness, implementability, and cost. The selected representative process options provide a basis for developing performance specifications during preliminary design. Although specific process options are selected for alternative development and evaluation, these process options are intended to represent the broader range of process options within a general technology type. The specific process for implementation of the remedial action may not be selected until the RD phase. Table 3-2 identifies the soil representative process options chosen for further evaluation.

3.2.3 Evaluation of Technologies and Representative Process Options

Following the preliminary screening, retained technologies and process options are evaluated in greater detail prior to being selected for use in developing remedial alternatives. One representative process option is selected, if possible, from each technology category to simplify subsequent development and evaluation of alternatives without limiting flexibility during remedy selection or RD. The evaluation criteria include effectiveness, implementability, and cost, with a focus on effectiveness. Brief descriptions of the criteria are summarized below.

3.2.3.1 Effectiveness

This criterion focuses on the potential effectiveness of process options in handling the estimated volume of media and meeting the remediation goals; the potential impacts to human health and the environment during construction and implementation; and how proven and reliable the process is with respect to the contaminants and conditions at the site.

3.2.3.2 Implementability

The implementability evaluation encompasses both the technical and institutional feasibility of implementing a process. Technical implementability was used in developing GRAs as an initial screen of technology types and process options to eliminate those that are clearly ineffective or unworkable at a site. Therefore, this subsequent, more detailed evaluation of process options places greater emphasis on the institutional aspects of implementability, such as the ability to obtain permits, availability of treatment, storage, and disposal services, and availability of necessary equipment and resources.

3.2.3.3 Cost

Cost plays a limited role in this screening. The cost analysis is based on engineering judgment, and each process is evaluated as to whether costs are high, low, or medium relative to the other options in the same technology type. If there is only one process option, costs are compared to other candidate technologies.

3.3 EVALUATION OF TECHNOLOGIES AND REPRESENTATIVE PROCESS OPTIONS

For the remediation of COCs in soil, a variety of technologies and process options are available for each of the GRAs described in Section 3.1. A range of these technology types and process options was identified and screened to focus on only the relevant technologies and process options for this site. A summary of the preliminary screening of technologies and process options appropriate for soil is provided in Table 3-1. The evaluation of the retained technologies and representative process options for soil remediation is provided in the following subsections. Only those technologies not eliminated in the preliminary screening or in the detailed evaluation presented in this section are included in Table 3-2 and retained for inclusion in remedial alternatives for soil.

3.3.1 No Action

The no-action response is required by the NCP and was retained to provide a basis for comparison with the other actions. This alternative, however, does not reduce COC migration or concentrations and would not meet the RAOs.

Conclusion: The no-action option is retained as a baseline, as required by the NCP.

3.3.2 Limited Action

Limited action includes minimum measures needed to reduce impacts to human health and does not include any direct remedial actions to protect the environment or minimize migration of COCs. This technology includes LUCs. The site access or usage restrictions of LUCs do not reduce soil concentrations, but they do reduce the potential for exposure.

LUCs commonly used to reduce exposure to contaminated media include restrictions on types of development allowed (e.g., no residential use), preventing the disturbance of remedy components (e.g., digging into cover systems), and limitations on certain types of construction (e.g., excavation, construction of buildings with basements). Because WFF is an active research, airfield, and military installation, some LUC measures are currently in place, such as the WFF Master Plan, base access restrictions, safety program, and work permitting processes, and others. LUCs are developed through a document referred to as a LUC RD after the ROD. A LUC RD could be developed for the specific LUC measures applicable for soil. As part of ICs, regular site inspections would be conducted to verify and enforce continued application of these controls.

- Effectiveness: LUCs could be applied to limit future use of the property. LUCs alone may not be effective in the long-term to reduce human health risk. LUCs are only effective if they are enforced properly. No additional risks to human health and the environment would directly result from the imposition of LUCs. LUCs without other remedial components would not address ecological risks in soil or sediment.

- Implementability: LUCs for soil on an active facility in the form of base instructions can be easily implemented by NASA. Before any property transfer occurs from NASA control, NASA would establish and record land use restrictions against any deed created for the transferred property. Monitoring and enforcement of land use restrictions would also be readily implemented by NASA.

- Cost: The costs associated with implementing LUCs would be relatively low. Capital costs would be very low, and relatively low long-term costs would be incurred for monitoring and enforcing LUCs.

Conclusion: LUCs are retained for development into remedial action alternatives. LUCs can be effective based on the restrictions placed. For example, a restriction that does not allow any residential use would prevent development of that area for residential use and prevent residential exposure, therefore mitigating risk to that receptor. To address industrial risks from lead in soil, for example, pregnant workers would be prohibited from or warned before traversing the site.

3.3.3 Containment

Containment measures are GRAs that utilize physical barriers to reduce potential threats to human health and the environment. The level of containment for a given site is generally selected based on the conditions present at the site and the physical and chemical properties of the COCs. Capping or covering includes the placement of a physical barrier on the surface of the contaminated soil—or consolidated materials excavated from another part of the site—to prevent direct contact with COCs and can reduce off-site migration of COCs via storm water runoff and migration through groundwater. Capping may be appropriate for those areas where excavation (removal) and disposal or soil treatment may not be implementable, effective, or cost-effective.

Permeable covers involve installing a soil barrier over the contaminated soil to assist in the restriction of access and exposure to the contaminated soil. Cover materials are typically natural materials but could include geosynthetic separation or marker layers. Soil covers can reduce the amount of leachate generated, prevent human contact with landfill contaminants and wastes, and prevent erosion and off-site migration of COCs from the surface of the landfill. A soil cover would include two layers as a minimum like a municipal solid waste landfill (RCRA Subtitle D regulations; 40 CFR 258.60), including a 6-inch thick vegetative/protective layer of earthen material that is capable of sustaining native growth and an 18-inch-thick layer of earthen material. An engineered impermeable cap could be used depending on the post-remediation site usage (e.g., parking lot), magnitude and types of contamination, or if controlling migration of contaminants to groundwater is required. An impermeable cap is not needed for the conditions at the Skeet Range MRS. Any cover system would require long-term operation and maintenance (O&M).

- Effectiveness: Installation of a soil cover would achieve the RAO for preventing direct exposure to contaminated soil and sediment. A soil cover would not be effective in preventing infiltration or potential leaching of contaminants from unsaturated soil to groundwater; however, the migration of COCs from soil to groundwater is not an issue for the COCs at this site. An impermeable cap would prevent infiltration and leaching. The effectiveness of a soil cover in preventing direct exposure to contaminants depends on maintenance over time. Because contaminated soil remains in place, LUCs would be required in conjunction with the soil cover to limit the future use of or intrusion into the covered areas.

- Implementability: Construction of a soil cover or impermeable cap is readily implementable at the site. Specialized construction techniques are not required, and qualified contractors and necessary cover materials are readily available. Site conditions are amenable to installation of cover/cap/barrier over a large area in the Southern Range Exposure Area. Soils and sediments can be removed from other exposure areas and consolidated under a cover in the large area. Remedial activities involving re-grading and capping are relatively common and can be conducted by general earthwork contractors. No permits or other administrative requirements would be necessary for construction activities (not considering the excavation of sediment in proximity to the palustrine forested wetland area). Contaminated soil would be left in place, so LUCs and long-term O&M would also be implemented.

- Cost: The capital costs for soil cover are moderate, depending on the size of the areas to be covered (and the amount of soil to be excavated from other areas for consolidation under the cover). The capital cost for an impermeable cover are higher. Both soil and impermeable covers would require long-term O&M costs.

Conclusion: Isolating areas of contaminated soils in place with a soil cover or consolidating excavated soils to one area under a soil cover, in conjunction with LUCs, would prevent exposure to contaminated soil and sediment. It should be noted that the waste is not permanently addressed with covering in place, but direct exposure is prevented with management practices in place. Soil cover is retained for further consideration in the development of remedial action alternatives. Impermeable capping is not retained because of the higher cost, and there are no leaching concerns based on the conclusions of the Site Investigation and RI (Tetra Tech, 2009a and 2020).

3.3.4 Removal

Removal is the physical extraction of COCs / contaminated media from their original location. Removal by itself cannot be a stand-alone remedial alternative as the removed material requires disposal or treatment and disposal. Bulk excavation involves the large-scale removal of contaminated soil/sediment. Selective excavation involves the removal of limited or localized areas of contaminated soil/sediment. Traditional excavation equipment such as hydraulic excavators, bulldozers, wheel loaders, and off-road dump trucks are typically used. The excavated material could be loaded onto trucks and hauled to an approved TSD facility or to a consolidation area on-site to be covered (see Section 3.3.3). Open excavations would be backfilled using clean fill.

- Effectiveness: Excavation is an effective technology to address contaminated soil at the site. This technology, combined with subsequent treatment, consolidation under cover, and/or disposal, would be a permanent solution and achieve the RAOs. The principal risks associated with excavation involve the potential migration of the excavated material by dust entrainment and erosion during handling. These concerns would be minimized by dust control measures (e.g., wetting), erosion and sediment (E&S) controls, and secondary containment of the equipment.

- Implementability: Excavation is readily implementable for the soil and sediments. Specialized construction techniques are not required, and qualified contractors and necessary equipment are readily available. Excavation would require implementation of E&S control measures and administrative requirements for working in or near wetlands. If excavated materials are disposed of off-site, then transportation and TSD facility requirements must be met.

- Cost: The capital costs range is dependent on the area(s) affected. Excavation of small localized hot-spots could be more cost-effective for on-site consolidation. Assuming typical unit costs for excavation, backfill, and on-site consolidation or off-site disposal, the total cost of such a scenario would be considered moderate.

Conclusion: Excavation is effective and implementable. As excavation is a precursor to other remedial options including disposal, treatment, and/or containment, it is retained for further evaluation. Removal of contaminated soil and sediment by bulk and/or selective excavation is retained for development of remedial action alternatives.

3.3.5 Treatment

In situ or ex situ treatment involves the mixing of an additive material into or with the soil matrix or changing its physical or chemical properties to reduce the toxicity, mobility, or volume of contaminants. Another GRA is always applied with in situ treatment to monitor the effects of mixing or, e.g., thermal treatment, on site conditions and the surrounding environment. For example, in situ treated soils might be removed for disposal. Under USEPA's (1998) Area of Contamination (AOC) Policy, remediation wastes may be consolidated and treated within an AOC (i.e., the site) without triggering land disposal restrictions or minimum technology requirements normally associated with RCRA waste management. Thermal technologies are eliminated due to the relatively low volume of organic contamination (PAHs). Soil vapor extraction and biological treatments are not applicable to the lead contamination. In situ soil flushing would allow lead to migrate to the water table and would not address lead shot in soil (in situ or ex situ). Chemical stabilization can convert leachable lead into insoluble minerals and mixed mineral forms within the material or waste matrix as nonhazardous waste; however, it does not address PAH contamination.

- **Effectiveness**: Stabilization treatment is an effective method for addressing the mostly lead-contaminated soil by reducing its toxicity and mobility. This would not affect or address the PAH contamination. When combined with other GRAs, its effectiveness increases by reducing the potential of [lead] hazardous waste generation. However, stabilized lead soils left in place may not be effective in the long-term; monitoring would be required. Stabilization would be highly effective to treat excavated lead-contaminated soils—if hazardous by RCRA characteristic—prior to off-site disposal as nonhazardous waste.

- **Implementability**: Treatment of lead and lead shot by chemical stabilization is considered implementable if needed. Equipment, reagent chemicals, and licensed contractors are readily available. In-place mixing and/or on-site consolidation for treatment is a common practice for lead-contaminated soils and is allowable by USEPA's AOC Policy. It has been widely tested and implemented at various remediation sites and is reduces the leachability of lead.

- **Cost**: Costs for chemical stabilization are based on the area/volume of soil to be treated. Costs would be low (or significantly reduced) when considering the off-site disposal of potential [lead soil] hazardous waste.

Conclusion: Chemical stabilization of lead in situ or ex situ is effective way to minimize the mobility of lead from soils and to ensure nonhazardous waste characterization. It is relatively easy to implement, and its cost depends on the volume of material to be treated. The costs for chemical stabilization are outweighed by the savings of not transporting and disposing of hazardous waste. The technology does not apply to PAHs, but PAH contamination at the site accounts for less than 10 percent of the volume of contaminated soil to be addressed at the site.

3.3.6 Disposal

Disposal can be accomplished by the placement and consolidation of contaminated soils in an off-site permitted landfill or waste treatment facilities. Disposal options for the contaminated soils are dependent on their physical and chemical characteristics. The types of landfills considered are hazardous waste landfills and nonhazardous waste landfills. Nonhazardous waste landfills include municipal waste landfills and construction/demolition waste landfills. Hazardous and nonhazardous waste landfills are currently available off-site to accept wastes.

Disposal in this case is not the same as on-site consolidation under a cover as described in Section 3.3.3. Disposal at the facility is not allowed. Excavated waste for disposal would be containerized and transported to an off-site TSD facility for final treatment or disposal (see Section 3.3.4). Characterization of the waste materials would be required to identify the proper disposal options. It is anticipated that hazardous waste (lead by characteristic) would be treated on-site to allow for transportation and disposal as nonhazardous waste at a RCRA Subtitle D landfill (see Section 3.3.5). That is, hazardous waste disposal is not considered further.

- <u>Effectiveness</u>: Disposal of contaminated soil at a landfill would achieve the RAOs by preventing direct exposure to and erosive transport of COCs in soil. The technologies available include a hazardous waste landfill and a nonhazardous waste landfill. The selection of one landfill over another depends on the relative toxicity of the contaminated soil, the risks associated with their disposal, and the regulatory requirements. As stated above, any remediation-derived waste that is hazardous by characteristic for lead would be treated on-site with chemical stabilization to allow for nonhazardous disposal (see Section 3.3.5). Off-site disposal would be a permanent solution and achieve the RAOs.

- <u>Implementability</u>: Off-site disposal is implementable. Transportation requirements must be met to transport the contaminated soil from WFF. Treatment of the contaminated soil, in compliance with RCRA land disposal restrictions (LDRs), may be required depending on waste characterization results for lead. Off-site disposal facilities are available, and equipment and resources needed to [treat if needed and] transport the contaminated soil are readily available and have been used for other remedial actions at WFF.

- <u>Cost</u>: For disposal in off-site landfills, the capital costs are moderate to high depending on the transportation distance to the landfill. The potential to use the excavated soils as alternate daily cover at a landfill would decrease the tipping fee significantly. Disposal in hazardous waste landfills is the most expensive of the landfill options, while disposal in a nonhazardous waste landfill is less expensive. As described above, any hazardous soils would be chemically treated on-site to allow for nonhazardous disposal and net cost savings.

Conclusion: Off-site disposal is an effective technology that would support the removal of contaminated soil and is implementable when using existing off-site disposal facilities. However, while it is a permanent solution on-site, it should be noted that the waste is not permanently addressed off-site with land disposal; the location of the waste is simply transferred from the site to a facility with management practices in place. It is generally appropriate to address small quantities of contaminated soils or COCs with impracticable or cost-ineffective treatment options. Off-site disposal is retained for development of remedial action alternatives.

3.3.7 Summary of Retained Technology and Process Options for Soil

Table 3-2 shows the technologies and process options retained for development of remedial alternatives for contaminated soil.

3.4 DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

3.4.1 Rationale for Development of Remedial Alternatives

Remedial alternatives are developed to comply with regulatory criteria applicable to the site conditions and the media of concern. As defined in the NCP, the goal for the FS process is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste. The criteria for identifying potentially applicable technologies to achieve these goals are provided in USEPA (1988) guidance and the NCP. A statutory preference for remedies that will result in a permanent and significant decrease in toxicity, mobility, or volume of the hazardous substance, pollutant, or contaminant and provide long-term protection is identified in Section 121 of CERCLA, as amended. In addition, the NCP requires that certain expectations be considered in developing and screening remedial alternatives. These expectations are as follows:

- Treatment will be used to address the principal threats posed by the site, wherever practical. Principal threats are liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials, if present.

- Engineering controls, such as containment, will be used for waste that poses a relatively low, long-term threat and for which treatment is impractical.

- A combination of methods will be used, as appropriate, to achieve protection of human health and the environment. In appropriate site situations, treatment of principal threats will be combined with engineering controls and institutional actions for treatment residuals and untreated waste.

- ICs, such deed restrictions, deed notices and local ordinances, will be used to supplement engineering controls for short- and long-term management to prevent or limit exposure to hazardous substances, pollutants, or contaminants.

- The use of innovative technologies will be considered when such technologies offer the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance than previously demonstrated technologies.

- Environmental media will be returned to their beneficial uses, wherever practical, within a time frame that is reasonable, given the particular circumstances of the site. When restoration of a medium is not practical, actions are expected to prevent further migration and exposure to contaminated media and to evaluate further risk reduction measures.

The primary purpose of the FS is to evaluate the information provided in the previous Site Investigation and RI reports (Tetra Tech, 2009a and 2020), assess site conditions, and develop an appropriate range of remedial alternatives to allow remedy selection. The development of alternatives should reflect the scope and complexity of the site problems that are being addressed. Development of alternatives for the site is based on the following:

- Technologies and process options remaining after the screening evaluations
- Land use and exposure scenarios
- PRGs
- ARARs

The purpose of providing a range of alternatives is to ensure that all reasonable GRAs are represented and evaluated. A range of alternatives is required by CERCLA to develop alternatives that differ in time to cleanup, cost, scope of remediation, and to evaluate different remedial process options that provide differing benefits and detriments. The technically feasible technologies retained for further evaluation in the above text and in Table 3-2 are combined to form remedial alternatives that provide varying levels of risk reduction, permanence, and cost.

3.4.2 Assembled Remedial Alternatives

Detailed descriptions and evaluations of these alternatives are presented in Section 4.0. The following alternatives were developed to address the soil/sediment COCs for the hypothetical future residential risk from exposure to lead and PAHs in surface soil, current/future industrial risk from exposure to lead in soil, and ecological risk from exposure to lead in soil and sediment and lead shot in soil. The key components of Alternatives 1 through 3 are summarized below and in Table 4-1.

- **Alternative 1–No Action**.

- **Alternative 2–Excavation and Off-Site Disposal.** Excavate soils and sediments in AAs and backfill with clean soil to promote revegetation and site restoration. Lead-contaminated soils that are characterized as hazardous would be chemically treated on-site to stabilize the leachable lead and allow for nonhazardous disposal. Excavated areas would be backfilled with soil to restore previous physical site conditions.

- **Alternative 3–Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs.** Excavate soils and sediment in AAs in the High Tower Range, Northern Range, and Skeet Range Shooting Exposure Areas, and portions of the Southern Range Exposure Area, consolidate and spread over the large contaminated soil area in the Southern Range Exposure Area, and topped with a vegetative soil cover. Excavated areas will be backfilled to restore previous physical site conditions. LUCs and long-term O&M would be performed to monitor compliance and effectiveness.

3.4.3 Screening of Remedial Alternatives

In the screening process, alternatives are evaluated generally regarding effectiveness, implementability, and cost. The purpose of the evaluation is to control the number of alternatives that will undergo a more thorough and extensive analysis so that the detailed evaluation in Section 4.0 focuses on the most plausible array of remedial alternatives. If possible, the alternatives carried forward for detailed evaluation should include the full range of alternatives recommended in the NCP and USEPA (1988) guidance: No action, treatment, and containment.

3.4.4 Screening Results

The alternative screening process for soil resulted in three identified alternatives being retained for further evaluation to preserve a full range of representative and plausible remedial actions. Alternative 1 is retained as a baseline alternative for comparison purposes per NCP. Alternative 2 would provide for UU/UE, so it is retained. Alternative 3 would be protective of human health and the environment and meet the RAOs, so is retained; however, it would not provide for UU/UE due to long-term management of the soil cover with LUCS and O&M. Detailed descriptions and evaluations of these retained alternatives are presented in Section 4.0. The following section presents the alternative evaluation criteria.

3.5 CRITERIA FOR DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

3.5.1 Evaluation Criteria

In accordance with the NCP (40 CFR 300.430), the following nine criteria are used for the evaluation of remedial alternatives:

- Overall Protection of Human Health and the Environment
- Compliance with ARARs and TBCs
- Long-Term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, or Volume through Treatment
- Short-Term Effectiveness
- Implementability
- Cost
- State Acceptance
- Community Acceptance

3.5.1.1 Overall Protection of Human Health and the Environment

Remedial alternatives must be assessed for adequate protection of human health and the environment in both the short- and long-term. The remedial alternatives must be able to diminish the unacceptable risks posed by hazardous substances or contaminants present at the site by eliminating, reducing, or controlling exposure to levels exceeding remediation goals.

For those sites where hazardous substances remain, and UU/UE are not allowable, engineering controls, ICs, or some combination of the two must be implemented to control exposure and thereby ensure reliable protection over time. In addition, implementation of a remedy cannot result in unacceptable short-term risks or cross-media impacts regarding human health and the environment.

3.5.1.2 Compliance with ARARs and TBCs

Remedial alternatives must be assessed to determine whether they attain ARARs and TBCs under federal environmental laws and state environmental or facility citing laws. If one or more regulations that are applicable cannot be complied with, then a waiver must be invoked.

3.5.1.3 Long-Term Effectiveness and Permanence

This criterion reflects CERCLA's emphasis on implementing remedies that will ensure protection of human health and the environment in the future, as well as in the near term. In evaluating alternatives for their long-term effectiveness and the degree of permanence they afford; the analysis should focus on the residual risks that will remain at the site after the completion of the remedial action. This analysis should include consideration of the following:

- Degree of threat posed by the hazardous substances remaining at the site.
- Adequacy of any controls (e.g., engineering controls and ICs) used to manage the hazardous substances remaining at the site.
- Reliability of those controls.
- Potential impacts on human health and the environment, should the remedy fail, based on assumptions included in the reasonable maximum exposure scenario.

3.5.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion addresses the statutory preference for remedies that employ treatment as a principal element by ensuring that the relative performance of the various treatment alternatives in reducing toxicity, mobility, or volume will be assessed. Specifically, the analysis should examine the magnitude, significance, and irreversibility of reductions.

3.5.1.5 Short-Term Effectiveness

This criterion examines the short-term impacts of the alternatives (i.e., impacts of the implementation) on the neighboring community, the workers, or the surrounding environment, including the potential threat to human health and the environment associated with excavation, treatment, and transportation of hazardous substances. The potential cross-media impacts of the remedy and the time to achieve protection of human health and the environment are also evaluated.

3.5.1.6 Implementability

The ease or difficulty of implementing the alternative is assessed considering the following types of factors, as appropriate:

- Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, reliability of the technology, ease of undertaking additional remedial actions, and ability to monitor the effectiveness of the remedy.
- Administrative feasibility, including activities needed to coordinate with other offices and agencies and the time required to obtain approvals from other agencies.
- Availability of services and materials, including the availability of adequate offsite treatment, storage capacity, and disposal capacity and services; availability of necessary equipment, specialists, and additional resources; availability of services and materials; and availability of prospective technologies.
- Sustainability of an alternative is discussed and includes consideration of the relative size of the associated carbon footprint, material usage, and environmental benefit.

3.5.1.7 Cost

Costs for remedial alternatives include both capital costs and long-term / future periodic costs (e.g., O&M, LUCs, Five-Year Reviews). Capital costs include both direct and indirect costs expected at the time of alternative implementation. Future costs are the post-construction costs required to ensure the continued effectiveness of the remedial action. Present-worth analysis allows the cost of remedial action alternatives to be compared on the basis of a single figure representing the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the life of the remedial project. The focus during the detailed analysis is on the Present Value (PV) of these costs.

Costs are used to provide stakeholders with information regarding the least expensive or most cost-effective alternative that will achieve the RAOs. For purposes of calculating the PV for the long-term costs (e.g., LUCs and O&M), a 30-year maintenance life and a 0.4 percent annual real discount rate typically are used (Office of Management and Budget [OMB], 2019). However, alternatives with long-term costs beyond 30 years can warrant PV estimates over longer periods. The cost estimates for this section are provided to an accuracy of +50 percent to -30 percent. The alternative cost estimates are in the fiscal year dollars as indicated and are based on conceptual design from information available at the time of this study. The actual cost of the project would depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables. Most of these factors are not expected to affect the relative cost differences between alternatives.

3.5.1.8 State Acceptance

This criterion, which is an on-going concern throughout the remediation process, reflects the statutory requirement to provide for substantial and meaningful state involvement.

3.5.1.9 Community Acceptance

This criterion refers to comments from community members on the remedial alternatives under consideration, where “community” is broadly defined to include all interested parties. These comments are considered throughout the CERCLA process. The community acceptance criterion is evaluated as part of the responsiveness summary presented in the ROD after the public comment period on the PRAP is held.

3.5.2 Relative Importance of Criteria

Under the NCP, the selection of the remedy is based on the nine evaluation criteria, which are categorized into three groups:

- Threshold Criteria: These criteria must be satisfied for an alternative to be eligible for selection. The threshold criteria are overall protection of human health and the environment and compliance with ARARs.

- Primary Balancing Criteria: The balancing criteria are used to weigh the relative merits of alternatives. The five criteria that are included are long-term effectiveness and permanence, the reduction of toxicity, mobility, or volume through treatment, short-term effectiveness, implementability, and cost.

- Modifying Criteria: State acceptance and community acceptance are modifying criteria that must be considered during remedy selection. These last two criteria cannot be evaluated until a preferred remedy has been presented.

The first seven criteria are specifically addressed in this FS. State acceptance will be evaluated after VDEQ has reviewed and commented on the draft FS report. Community acceptance will be addressed in the ROD that will be finalized after the public comment period for the PRAP. Therefore, seven of the nine criteria are evaluated in this FS.

4.0 DESCRIPTION AND DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES FOR SOIL

The purpose of this section is to describe the remedial alternatives developed in Section 3.0 for the remediation of the soil and sediment at the site, to analyze the remedial alternatives against the NCP evaluation criteria, and to present a comparative analysis of the alternatives relative to the specific evaluation criteria. The remedial action will address soil and sediment from 0 to 1 foot bgs to address unacceptable risks identified in the HHRA and ERA. The remedial action alternatives evaluated for soil and sediment are as follows:

- **Alternative 1–No Action**
- **Alternative 2–Excavation and Off-Site Disposal**
- **Alternative 3–Excavation, On-Site Consolidation Under Soil Cover, O&M, and LUCs**

4.1 DESCRIPTION OF REMEDIAL ALTERNATIVES

The alternatives described in the sections below were developed to address the soil and sediment in the lead, lead shot, and PAH AAs/TRZs at the site (Figure 2-2). An abbreviated summary of these alternatives is provided in Table 4-1.

With respect to both Alternatives 2 and 3: Prior to any construction, even clearing activities, there are several required upfront tasks associated with working near sensitive ecological habitats or cultural resources at WFF (e.g., Atlantic Ocean, Chesapeake Bay, Little Mosquito Creek, etc.).

1. **Federal Consistency Determination**: On-site construction activities, even under CERCLA, must comply with substantive requirements of the Coastal Zone Management Act, as amended (also see Table 4-4–Location-Specific ARARs). The intent is to ensure that if NASA determines the "Proposed Action" will have reasonably foreseeable effects on coastal resources, then the action must be *consistent* with Virginia's Coastal Zone Management Program (i.e., review which enforceable policies apply based on a review of the Proposed Action's effects on coastal zone uses and resources). This is partially reliant on the Biological Evaluation (see below). For example, during a previous remedial action at WFF, the efforts were to be consistent with wetlands and dunes management.

2. **Biological Evaluation**: This is a study of the proposed construction's anticipated *Action Area*—the effects on threatened or endangered species or their habitat to be impacted physically or disturbed by noise, sound, vapors, line-of-site, etc.—under U.S. Fish and Wildlife's (USFWS's) jurisdiction or by agreement between USFWS and NASA (also see Table 4-4–Location-Specific ARARs). Subsequent actions that may be required or requested by USFWS are related to NASA-determined effects to verifiably identified species or their habitat. For example, during a previous remedial action at WFF, a tree and bat survey was required prior to any tree clearing (greater than 3 inches in diameter) to ensure no significant impact to roosting northern long-eared bats (*Myotis septentrionalis*).

3. **Cultural Resources Evaluation**. This is a desktop-like study to determine any cultural resource elements and historic artifacts potentially at the site to comply with the National Historic Preservation Act, as amended (see Table 4-4–Location-Specific ARARs). If *Potential* or *Eligible* areas of effect are identified, then the project may proceed by either 1.) conducting a Phase 1 archeological survey (background research, visual assessment/site walkover, and subsurface

archeological excavations) before clearing and excavation work begins, submitting a Phase 1 Report to VDHR, and getting VDHR approval; or 2.) having on-site archaeological support during clearing and excavations and producing an archaeological sensitive assessment deliverable after construction. A desktop-like study was performed prior to the removal actions at the former Pistol and Rifle Ranges in 2016, and an initial review indicates portions of any remedy at the Skeet Range MRS indeed will occur within culturally restricted areas. NASA will coordinate with VDHR and appropriate Native American tribes. VDHR and appropriate Native American tribes will be notified of any artifacts and/or human remains encountered during ground disturbance activities.

NASA forwarded the Draft FS to the Catawba Indian Nation for review and comment. In a June 8, 2021 letter they stated, "The Catawba have no immediate concerns with regard to traditional cultural properties, sacred sites or Native American archaeological sites within the boundaries of the proposed project areas. However, the Catawba are to be notified if Native American artifacts and/or human remains are located during the ground disturbance phase of this project."

4. **Wetland Delineation and Permitting**: A wetland delineation is a field observation and measuring effort, followed by a report, to identify the location and extent of wetlands and other waters of the U.S. within or near the remedial action construction. The USACE makes a jurisdictional determination, even if just preliminary, based on NASA's submitted materials and requested review; USACE issues a confirmation of the non-binding determination and reminds to minimize or eliminate negative impacts to wetlands (e.g., do not discharge dredged materials and control sediment transport during construction within and near the wetlands). Further administrative elements are addressed by RPM Team review of the RD/work plan. A new wetland delineation may not be necessary at the Skeet Range MRS considering the wetland evaluation performed during the RI in 2018 (see Appendix F in the 2020 RI Report). The evaluation updated previous delineations and habitat surveys to determine the boundary of the palustrine forested wetland shown on Figure 1-2 and others. The relatively small wetland portion (1,700 square feet or 0.04 acre) to be excavated would address ecological risk from exposure to lead in the drainage area.

These upfront efforts are required for any construction alternative. The same costs and durations of these upfront elements are included in each of Alternatives 2 and 3. Therefore, these elements are not used for comparing the alternatives.

4.1.1 Alternative 1 – No Action

The no-action alternative is developed as a baseline scenario to which the other alternatives may be compared, as required by the NCP. The no-action alternative would involve no remedial response activities and would provide no additional protection of human health. Under this alternative, no remedial actions or measures would be implemented to address risks (or ARAR-based-PRG exceedances) associated with COCs in soil or sediment.

4.1.2 Alternative 2–Excavation and Off-Site Disposal

Key components of Alternative 2 are identified on Table 4-1 and depicted on Figure 4-1. Alternative 2 would involve the excavation of lead-, lead shot-, and PAH-contaminated soils and sediments from the site followed by the off-site disposal of excavated wastes in accordance with ARARs (see Tables 4-2, 4-3, and 4-4). In addition to the common upfront components (see beginning of Section 4.1), this alternative consists of the following major components: Site preparation, soil excavation confirmation sampling, waste characterization, off-site waste disposal, and site restoration. In addition, on-site stabilization of lead in soil may be performed prior to off-site disposal.

Site preparation includes mobilization and setup of support facilities, utility clearance surveys, vegetation removal, temporary road construction, and establishment of soil E&S controls. Equipment and support facilities (e.g., excavators, loaders, office trailer, storage containers, sanitary facilities, etc.) would be mobilized to the site and set up or staged at approved locations. Utility clearance surveys, vegetation removal, and temporary road construction would be conducted where necessary to expose or provide access to the areas marked for excavation. E&S control measures (e.g., silt fence and straw bales) would be established to ensure that soil disturbance activities do not adversely impact downgradient surface water bodies, floodplains, tidal marshes, or wetlands. During vegetation clearance, temporary road construction, soil excavation and stockpiling, waste loading, backfilling, and regrading operations, E&S controls would be regularly inspected and maintained until excavation and backfilling is complete and the site vegetation is re-established. An E&S Control Plan would be prepared as part of the RD/work plan, in accordance with the substantive stormwater runoff protection requirements of VDEQ and the State Water Control Board.

Excavation operations would be performed by qualified excavation personnel with current Hazardous Waste Operations and Emergency Response (HAZWOPER) training, as required by Occupational Safety and Health Administration (OSHA). Standard dust control techniques would be used during removal activities to mitigate fugitive dust emissions. Excavation areas would be cordoned off during the excavation to prevent any trespassers from being exposed to contamination until the contaminated soil is removed.

All lead-, lead shot-, and PAH-contaminated soils and sediments with concentrations greater than their respective PRGs would be excavated, characterized, and direct-loaded or containerized for transportation and off-site disposal. This alternative would be designed and implemented in a manner that complies with ARARs (see Tables 4-2, 4-3, and 4-4). Contaminated soil/sediment would be permanently removed, thereby eliminating all unacceptable ecological and human health risks and minimizing the potential for future contaminant migration. Contaminated soil and sediment would be excavated from within the AA boundaries (multiple TRZs for lead, lead shot, and PAHs) shown on Figures 2-2 and 4-1. Excavation and backfill would be conducted at TRZs L1/LS1, L2/LS2, LS3, PAH1, PAH2, and PAH3 to an approximate depth of 1 foot bgs (Figure 4-1). TRZs L1 and LS1, and similarly TRZs L2 and LS2, have overlapping portions; excavations would address both the lead and lead shot in the overlapping areas. TRZ L1 also includes TRZ L1 Sediment.

TRZ L1 Sediment is the portion of TRZ L1 that is within the palustrine forested wetland habitat, where some surface soil was evaluated as sediment in the ERA (see Section 1.7). The not-to-exceed-PRG for addressing ecological risks for exposure to sediment is 530 mg/kg. For soil, the ecological not-to-exceed-PRG is 750 mg/kg and the average-PRG is 240 mg/kg (see Section 2.4 and Tables 1-1 and 2-1). The HHRA evaluated the soil/sediment as soil; the lead average-PRG for human health is 200 mg/kg, which is more conservative than the ecological-based average-PRG. Therefore, addressing soil/sediment to reduce the average lead concentration in the Northern Range Exposure Area to 200 mg/kg—and ensuring that not-to-exceed PRGs are not exceeded—will address risks to both human health and ecological risk. This would also address sediments in the palustrine forested wetland with concentrations exceeding the ecological-based sediment invertebrate not-to-exceed-PRG of 530 mg/kg.

The soil/sediment quantity estimates are calculated and discussed in Appendix B–Quantity Calculations and summarized below (also see Section 2.6–Estimation of Areas and Volumes).

TRZ	COC(s)	Size (acre)	In Situ Volume (BCY)	Ex Situ Volume (LCY)	Weight (Tons)
L1/LS1	Lead and Lead Shot	1.26	2,030	2,436	3,044
L1 Sediment	Lead	0.04	63	76	94
L2/LS2	Lead and Lead Shot	2.00	3,233	3,880	4,850
LS3	Lead	0.06	104	124	156
PAH1	PAHs	0.19	311	373	467
PAH2	PAHs	0.02	29	35	43
PAH3	PAHs	0.11	178	213	267
Total*		**3.65***	**5,884***	**7,061***	**8,827***

*Overlapping areas removed to avoid double-counting: L1 Sediment (within L1), L1/LS1 overlap, and L2/LS2 overlap.
BCY – Bank cubic yards (i.e., in situ volume)
LCY – Loose cubic yards (ex situ expanded volume after digging and handling [i.e., disposal or handling volume])

Approximately 5,890 BCY of contaminated soil/sediment—5,370 BCY of which is lead and lead-shot-contaminated soil/sediment and 520 BCY of which is PAH-contaminated soil—would be excavated under Alternative 2. Approximately 65 BCY of this would be lead-contaminated sediment from the palustrine forested wetland area in the Northern Range Exposure Area (see Figure 2-1 and Figure 4-1). The total volume is anticipated to expand by approximately 20 percent to 7,060 LCY and weigh approximately 8,830 tons for off-site disposal in accordance with ARARs. No drying agent is anticipated to be needed for the relatively small volume of sediment when it is mixed in with other excavated soils.

Waste characterization sampling would be performed (either pre-construction in situ or after excavation while staged) for analysis of full TCLP, total petroleum hydrocarbons (TPH)–diesel range organics (DRO), and total benzene, toluene, ethylbenzene, and xylenes (BTEX). TPH and BTEX analyses will provide data to the disposal facility about whether the material can be used as alternate daily cover at a landfill (for a lower tipping fee). Soil with TCLP lead concentrations greater than 5.0 mg/L based on waste characterization sampling results would be classified as hazardous waste based on lead toxicity and, thus, would be subject to special transportation and disposal requirements. Investigation-derived waste characterization results from previous investigations (see Section 1.3.3) indicate nonhazardous lead conditions. To be conservative in cost-estimating, it is assumed that 25 percent of the excavated soils would be hazardous for lead by characteristic. This hazardous soil would be treated on-site—prior to off-site transportation and disposal—to stabilize the leachable lead and render it nonhazardous.

Under USEPA's (1998) AOC Policy, remediation wastes may be consolidated and treated within an AOC without triggering land disposal restrictions or minimum technology requirements normally associated with RCRA waste management (see Section 4.2.2.2). A common treatment technology for lead-contaminated soils is chemical stabilization. This technology has been widely tested and successfully implemented at numerous remediation sites and is considered a reliable treatment technology for rendering lead contaminated soils nonhazardous. Chemical stabilization converts leachable lead into insoluble minerals and mixed mineral forms, thereby minimizing the ability of lead to mobilize under the more acidic conditions in a landfill.

For the purposes of developing a cost estimate for this alternative, the treatment process is assumed to be chemical stabilization through the application of Maectite®, a phosphate-based liquid and powder reagent that binds leachable lead in soil within 3 to 5 hours (Sevenson, 1999 and 2020). This reagent can be applied in situ or in staged piles or consolidated area(s) within the site and mechanically blended, as necessary, using traditional earth-moving equipment (e.g., excavator) to ensure complete contact with the contaminated soil. Once the chemical reaction is complete, the resulting mixture can be managed as nonhazardous waste for transport to and disposal at a Subtitle D landfill. Stabilized soil would be tested to confirm nonhazardous lead characteristic.

The waste treatment process may require a treatability study be conducted prior to implementation to determine the optimal ratio of reagent-to-soil necessary to meet the treatment goal of 5.0 mg/L. The treatability study would be conducted using representative site soils and various proportions of reagent to ensure that the treatment design can consistently render the waste nonhazardous. Once the proper proportions are determined and treatment process is underway, waste composite samples would be collected from a representative portion of the treated soils to verify compliance with the waste facility acceptance criteria.

The confirmation sampling program would be developed by the RPM Team prior to initiating the selected remedy. Confirmation samples would be collected from the sidewalls of each excavation area and analyzed for the COCs to verify that PRGs have been met. This could be completed prior to construction or during construction. Bottom-excavation sampling may not be necessary—considering there are no unacceptable risks for exposure to soils deeper than 1 foot—based on analytical data from previous investigations (see Section 1.3.3) and the risk assessments (see Sections 1.6 and 1.7). Based on the confirmation sampling results, additional excavation would be conducted, as necessary, to remove residual soil with concentrations exceeding PRGs.

After confirming that cleanup to the PRGs has been achieved, the excavated areas would be backfilled with clean backfill material from off-site borrow sources. The backfill material would meet prescribed specifications for chemical constituents, as certified through laboratory analysis. The excavated areas would be backfilled to approximate original grade, ensuring appropriate site drainage. The backfilled areas would be compacted, as necessary, to ensure slope stability and covered with 6 inches of imported clean topsoil. All disturbed areas (estimated at 4.4 acres for Alternative 2) would be revegetated with at least native grasses and E&S controls would remain in place until vegetation is sufficiently re-established. The native grass seeding for all areas (and vegetation, shrub, and/or tree plantings in TRZs L1, LS1, and L1 Sediment) will be determined with WFF Natural Resources and the regulators during the Remedial Design phase following the ROD. Approximately 2,950 BCY of topsoil and 2,950 BCY of clean backfill would be needed to restore all excavated areas to their original elevations.

4.1.3 Alternative 3–Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs

Key components of Alternative 3 are identified on Table 4-1 and depicted on Figure 4-2. In addition to the common upfront components (see beginning of Section 4.1), Alternative 3 would involve the excavation of lead-, lead shot-, and PAH-contaminated soils and sediments from some portions of the site followed by consolidating the materials in another portion of the site, covering the material with a RCRA D-equivalent-type soil cover, and then implementing and maintaining LUCs and performing O&M. This alternative would be designed and implemented to comply with ARARs (see Tables 4-2, 4-3, and 4-4) and comprise the following major components: Site preparation, soil excavation confirmation sampling, waste characterization, on-site consolidation and regrading, installation of soil cover, site restoration, and long-term post-construction O&M and LUCs. No off-site disposal would be included, but the same on-site stabilization of lead would be assumed for excavated soils to be consolidated and in situ soils to be covered.

Site preparation activities are like those of Alternative 2 (see Section 4.1.2), including the establishment of E&S controls. An E&S Control Plan would be prepared as part of the RD/work plan in accordance with the substantive stormwater runoff protection requirements of VDEQ and the State Water Control Board.

Excavation and earthwork operations would be performed by qualified excavation personnel with HAZWOPER training, using dust control measures, controlling site access during construction, etc.

Under Alternative 3 (see Figures 2-2 and 4-2), the lead- and lead-shot contaminated soils/sediment from TRZs L1 (includes L1 Sediment) and LS1 would be excavated from the High Tower and Northern Range Exposure Areas and consolidated in the Southern Range Exposure Area. As described above for Alternative 2, Alternative 3 also includes excavating TRZ L1 Sediment, which is a small portion of TRZ L1 located within the palustrine forested wetland habitat. The PAH-contaminated soils from TRZs PAH1 and PAH3 in the Skeet Range Shooting Exposure Area, as well as the isolated lead shot-contaminated soil from TRZ LS3 in the Southern Range Exposure Area, also would be excavated for consolidation. A portion of the lead- and lead-shot contaminated soil in TRZs L2/LS2 along the NOAA facility fence would be excavated for a 20-foot buffer to allow for proper consolidation under, and construction of, the soil cover (i.e., allow for the sloped sides of the soil cover). The excavated soil/sediment would be consolidated and graded in a 1-foot-thick layer over the remaining contaminated soil in the Southern Range Exposure Area to measure approximately 2 acres (i.e., TRZs L2/LS2 and PAH2; see Figure 4-2). That is, the remainder of the lead- and lead shot-contaminated TRZs L2/LS2 and the PAH-contaminated TRZ PAH2 would remain in place to be covered.

The quantity estimates for excavation, consolidation, and cover materials are calculated and discussed in Appendix B–Quantity Calculations and summarized below (also see Section 2.6–Estimation of Areas and Volumes).

TRZ	COC(s)	Size (acre)	In Situ Volume (BCY)	Ex Situ Volume (LCY)	Weight (Tons)
Excavation for consolidation					
L1/LS1	Lead and Lead Shot	1.26	2,030	2,436	3,044
L1 Sediment	Lead	0.04	63	76	94
LS3	Lead	0.06	104	124	156
PAH1	PAHs	0.19	311	373	467
PAH3	PAHs	0.11	178	213	267
NOAA Fence Line Buffer	Lead and Lead Shot	0.13	207	249	311
	Total*	**1.75***	**2,830***	**3,396***	**4,244***
Leave to be covered					
L2/LS2	Lead	1.88	3,026	3,631	4,539
PAH2	PAHs	0.02	29	35	43
	Total*	**1.89***	**3,055***	**3,666***	**4,582***
Soil Cover					
2-foot Clean Soil Barrier (including side slopes at 30% grade)		**2.33**	**7,212**	–	**10,818**

*Overlapping areas removed so as not to be double-counted: L1/LS1 overlap, L1 Sediment (within L1), L2/LS2 overlap, and NOAA Fence Line Buffer (within L2/LS2).
BCY – Bank cubic yards (i.e., in situ volume)
LCY – Loose cubic yards (ex situ expanded volume after digging and handling [i.e., disposal or handling volume])

Approximately 2,830 BCY of contaminated soil/sediment—2,340 BCY of which is lead- and lead-shot-contaminated soil/sediment and 490 BCY of which is PAH-contaminated soil—would be excavated under Alternative 3. This material would be hauled to the consolidation area and spread into a 1-foot-thick layer.

Approximately 65 BCY of this would be lead-contaminated sediment from the palustrine forested wetland area in the Northern Range Exposure Area (see Figures 2-2 and 4-2). The total volume is anticipated to expand by approximately 20 percent to 3,400 LCY and weigh approximately 4,250 tons to haul to the consolidation area for spreading and eventual cover. No drying agent is anticipated to be needed for the relatively small volume of sediment when it is mixed in with other excavated soils. Short of excavating the 20-foot buffer area along the NOAA fence line, the entirety of TRZs L2, LS2, and PAH2 would be left in place to be covered (by both consolidated excavated soil and the soil cover). The total footprint of the consolidated material and the soil cover is almost 2 acres; accounting for side-slopes from the 3-foot-high soil-covered material (e.g., 10 feet laterally assuming a 30% grade for proper drainage), the cover will measure approximately 2.33 acres.

The soil cover would consist of the installation of a series of cover layers: Geotextile as an indicator layer, a soil layer (as a barrier layer), and a vegetation layer. Approximately 7,210 BCY of additional clean fill and topsoil materials would be imported: 1.5 feet of clean fill (4,740 BCY) for the infiltration layer with 6 inches of topsoil (1,580 BCY) for the vegetative layer, and 890 BCY of clean fill for the 3:10 side slopes. Jute mats would be installed to support the establishment of the vegetation, especially on the side slopes of the cover. The vegetation—at least native grass seeding mix specified by NASA—would add to the soil cover's integrity by providing root biomass, reducing erosion and runoff. The roots of the plants also produce root exudates, which typically encourage the growth of microbes that could be beneficial in reducing or stabilizing site-related contaminants. While precipitation would percolate through the cover and consolidated in situ contaminated soil/sediment, the soil and groundwater data evaluated in the RI showed no impact on groundwater from contaminated soil and sediments in this environment. No specific compaction is required other than traversing back and forth with heavy equipment during filling and grading. E&S controls would remain in place until construction activities are complete the site vegetation is re-established. Permanent E&S controls after construction would include appropriate grading and site vegetation. The excavation, consolidation, and soil cover minimize potential future contaminant migration and address both ecological and human health risks by eliminating exposure pathways to COCs in the soil/sediment. Long-term O&M and LUCs ensure the integrity of the soil cover and protectiveness of Alternative 3.

Alternative 3 would require the same waste characterization sampling scheme as Alternative 2, except analysis of only TCLP metals would be required to check lead TCLP concentrations prior to covering on-site. This includes both the materials to be excavated for consolidation under the cover and for in situ soils also to be under the cover. Investigation-derived waste characterization results from previous investigations (see Section 1.3.3) indicate nonhazardous lead conditions. To be conservative in cost-estimating, it is assumed that the same amount (i.e., 25 percent) of the soils—excavated for consolidation under the cover or in situ under the cover—would be hazardous for lead by characteristic. This hazardous soil would be treated on-site under USEPA's (1998) AOC policy to stabilize the leachable lead and render it nonhazardous prior to installing the soil cover. Once the chemical reaction is complete, the resulting mixture can be maintained or consolidated as nonhazardous waste under the Subtitle-D-equivalent soil cover to be constructed on-site. Stabilized soil would be tested to confirm nonhazardous lead characteristic prior to installing the cover.

The confirmation sampling program would be developed by the RPM Team prior to initiating the selected remedy. Confirmation samples likely would be collected from sidewalls of each excavation area and analyzed for the COCs to verify that PRGs have been met. This could be completed prior to construction or during construction. Bottom-excavation sampling may not be necessary—considering there are no unacceptable risks for exposure to soils deeper than 1 foot—based on analytical data from previous investigations (see Section 1.3.3) and the risk assessments (see Sections 1.6 and 1.7). Based on the confirmation sampling results, additional excavation would be conducted, as necessary, to remove residual soil with concentrations exceeding PRGs and consolidate them on-site under the soil cover.

The LUC limits for Alternative 3 would be defined by the extent of bioengineered cover, including the side slopes. The LUCs associated with this alternative would include administrative controls, such as restrictions on residential development, digging, and other construction activities within the soil cover area, as well as periodic inspections of cap integrity (e.g., quarterly for the first 2 years to monitor erosion and vegetation, and annually thereafter). Periodic soil cover O&M would address cover and vegetative maintenance, as well as checking for and addressing animal burrows identified during LUC/cover inspections. Periodic monitoring of the disturbed wetland area may be conducted to document the natural re-establishment of wetland vegetation. Because contaminants would remain on-site following the implementation of Alternative 3, site reviews would be performed every 5 years until RAOs are met to evaluate site status, assess the protectiveness of the remedy, and to determine whether further action is necessary.

After confirming that the project PRGs have been achieved, the excavated areas would be backfilled with clean backfill material from off-site borrow sources as described for Alternative 2. Approximately 1,420 BCY of topsoil and 1,420 BCY of clean backfill would be needed to restore all excavated areas to their original elevations. Following the installation of the soil cover, all disturbed areas (estimated at 4.9 acres under Alternative 3) would be revegetated with at least native grasses and E&S controls would remain in place until vegetation is sufficiently reestablished.

4.2 DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

The evaluation of the alternatives provides information to facilitate selection of a specific remedy or combination of remedies.

4.2.1 Alternative 1–No Action

Consideration of a no action alternative is required under the NCP. At a minimum, it provides a baseline against which other alternatives may be compared. Under the no action alternative, no additional remedial measures would be implemented at the site to address the RAOs. No containment, removal, or treatment of soil contaminants would be conducted. The alternative would provide no mechanism to minimize potential risks to human or ecological receptors.

4.2.1.1 Overall Protection of Human Health and the Environment

Alternative 1 would not protect human health or the environment. No response actions would be taken to contain or remove the contaminated soils and sediments or prevent their migration, and no additional measures would be implemented to prevent potential human and ecological contact with the contaminated soils and sediments. COCs would continue to pose risks to the respective human health and ecological receptors in the long-term.

4.2.1.2 Compliance with ARARs

There are no actions, and, thus, no location- or action-specific ARARs associated with this alternative. This alternative would not comply with the chemical-specific TBCs.

4.2.1.3 Long-Term Effectiveness and Permanence

Since no remedial actions would occur under Alternative 1, the estimated risks of effects to human health and the environment would remain. Under the no-action alternative, no inspections or review of site conditions would be conducted, and no further determination of levels (e.g., monitoring) of COCs would be conducted. Similarly, there would be no review of property use to determine if persons were being exposed to COCs in soil. Under the no action alternative, no additional controls would be used to manage the COCs at the site. Therefore, the evaluation of the adequacy and reliability of new controls is not applicable.

4.2.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The no-action alternative would not reduce the toxicity, mobility, or volume of contamination because no treatment would be used to address contaminated soil. As a result, no hazardous substances would be treated or destroyed, and contaminated soil would remain in place. Alternative 1 would not satisfy the statutory preference for treatment to reduce risks posed by contaminated soil.

4.2.1.5 Short-Term Effectiveness

Since no response actions would be implemented, the no-action alternative would not pose additional short-term risks to the local community, base personnel, or the environment. However, none of the RAOs to protect human health and ecological receptors or to prevent contaminant migration would be achieved.

4.2.1.6 Implementability

This alternative would require no implementation. Implementation of the no-action alternative would not limit future implementation of additional remedial actions at the site, if deemed necessary.

4.2.1.7 Cost

There are no costs associated with Alternative 1 because no remedial actions or measures would occur.

4.2.2 Alternative 2–Excavation and Off-Site Disposal

Alternative 2 relies on removal/excavation of contaminated soils from 0 to 1 foot bgs from all of the AAs/TRZs shown on Figure 2-2 and collectively on Figure 4-1. The excavated soil would be disposed of off-site as nonhazardous waste; any soils determined to be hazardous for lead by characteristic would be treated on-site to stabilize the leachable lead under acidic landfill conditions (to make them nonhazardous for disposal). This alternative does not include post-construction site controls, other than monitoring the establishment of vegetation and removing the E&S controls at an appropriate time. This alternative would provide UU/UE status for the site.

4.2.2.1 Overall Protection of Human Health and the Environment

Alternative 2 would be protective of human health and meet RAOs under the current/future industrial and hypothetical future residential land use scenarios. This alternative would eliminate the risk by removing all soil and sediment at concentrations above cleanup goals. The lead stabilization process, if required, would be further protective of human health and the environment by stabilizing the leachable lead to transport and dispose of the material as nonhazardous waste.

4.2.2.2 Compliance with ARARs

Tables 4-2, 4-3, and 4-4 summarize compliance chemical-, location-, and action-specific ARARs and TBCs, respectively. Alternative 2 would meet the identified ARARs.

4.2.2.3 Long-Term Effectiveness and Permanence

Alternative 2 offers a permanent long-term effectiveness beyond that of Alterative 3. Excavation and off-site disposal of the contaminated soil/sediment is reliable and permanent for the site. Ecological receptor exposure and hypothetical future residential exposure would be prevented by the removal of the contaminated soil/sediment. No long-term maintenance or management would be required, and UU/UE status would be achieved.

4.2.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 2 would not include any active treatment technologies that would achieve reductions in the toxicity, mobility, or volume of contaminants in place at the site; however, prior to off-site transportation and disposal, lead stabilization treatment would be performed on any soils that are determined by waste characterization analysis to be hazardous by RCRA characteristic. The process of excavation would only move the contaminated material to a permitted landfill disposal facility. The mobility of contaminants in the environment would be reduced by placement of contaminated material in a permitted landfill, as well as any potential chemical stabilization of lead soils to reduce the leaching of lead under acidic conditions prior to removal from the site.

4.2.2.5 Short-Term Effectiveness

Alternative 2 would be effective in the short-term if work is done properly and with appropriate controls in place. With excavation and off-site transportation and disposal of the contaminated soil, controls would be implemented to protect remediation construction workers, the public, and the environment until site restoration is completed. Implementation of Alternative 2 is not expected to pose any significant risks to the local community, workers, or the environment. Workers who implement Alternative 2 would be adequately safeguarded by implementation of a site-specific health and safety plan (HASP) and the use of personal protective equipment (PPE). OSHA standards would be followed during all remedial activities. Increased truck and heavy equipment vehicular traffic would occur as the result of excavation and off-site transport of waste materials, in addition to importing clean backfill and topsoil (e.g., 400 truckloads to transport 8,830 tons of excavated soil and 400 truckloads to import the same amount of backfill and topsoil).

4.2.2.6 Implementability

Alternative 2 is readily implementable. No significant engineering, administrative, or construction difficulties are anticipated, although coordination with appropriate federal, state, and local agencies would be required. The labor, equipment, and materials necessary to implement this alternative are conventional and readily available. Multiple general and specialized contractors have the capability to perform the construction activities specified for this alternative, and disposal facilities permitted to accept contaminated soils classified as either hazardous or nonhazardous are available. From an annual budgetary standpoint for NASA and USACE/FUDS, Alternative 2 could be implemented in a phased approach (e.g., excavate and restore certain areas as budget allows).

Chemical stabilization (treatment) of lead soils has been widely tested and implemented at various remediation sites and is considered a reliable treatment technology for reducing the leachability of lead-contaminated soils. The RD/work plan would provide the specifications for treatment, soil removal, support of excavation, and site restoration. The necessary health and safety requirements for construction activities conducted as part of implementation of the remedy would be identified in the work plan. A traffic control plan would also be necessary due to the truck traffic to haul contaminated soil and clean fill materials.

Due to the presence of culturally sensitive areas within the AAs and TRZs, specific procedures will be implemented including notifying the VDHR and appropriate Native American tribes of any artifacts and/or human remains encountered during ground disturbance activities.

4.2.2.7 Cost

The capital cost for Alternative 2 is estimated to be $2,386,000. There are no future periodic or maintenance costs, so the PV total cost for Alternative S-3 is the same as the capital cost. Quantity calculations are presented in Appendix B and a detailed cost estimate is provided in Appendix C.

Cost estimates for individual line items are based on quotations from potential vendors and subcontractors, engineering estimates, recent similar project experience, and published values (e.g., RSMeans Costworks). If implemented, the actual cost of Alternative 2 would depend on the final scope and design parameters presented in the impending work plans, the schedule for implementation, competitive market conditions, actual scale weights of waste disposed, and other variables.

4.2.3 Alternative 3–Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs

Alternative 3 includes excavation of soils/sediments from several areas, consolidating them on top of other contaminated soil in a portion of the Southern Range Exposure Area, covering the consolidated contaminated materials and remaining in situ contamination with protective layers of soil as a barrier, performing O&M, and implementing and maintaining LUCs to achieve the RAOs. Certain AAs/TRZs will be excavated, backfilled, and restored, while others will remain in place or be covered (see Figure 2-2 and Figure 4-2). On-site stabilization of lead is conservatively assumed just like it is for Alternative 2.

4.2.3.1 Overall Protection of Human Health and the Environment

This alternative protects human health and the environment by prohibiting residential use of the site, controlling or monitoring construction activities and digging, and maintaining the cover (exposure barrier to the contaminated media). The soil cover integrity would be checked during LUC/cover inspections and maintained during long-term O&M to ensure no human health or ecological receptor exposure to underlying contaminated soils. The lead stabilization process, if required, would be further protective of human health and the environment by stabilizing the leachable lead before covering on-site under the soil cover.

This alternative does not provide UU/UE status for the site. While the site remains under the control of NASA, LUCs prohibiting residential development and O&M of the soil cover [barrier] integrity would be protective. Five-Year Reviews would assess whether the soil cover and controls in place are meeting the RAOs. If the property is transferred to a non-federal entity prior to meeting RAOs at the site, deed restrictions would be required.

4.2.3.2 Compliance with ARARs

Tables 4-2, 4-3, and 4-4 summarize compliance chemical-, location-, and action-specific ARARs and TBCs, respectively. This alternative would meet the identified ARARs.

4.2.3.3 Long-Term Effectiveness and Permanence

Alternative 3 would provide long-term effectiveness and permanence. Although the contaminated soil/sediment would remain on-site above levels that allow for UU/UE, preventing exposure to contaminated media using a 2-foot soil cover as a barrier would protect human and ecological receptors and contaminant migration. With appropriate O&M and LUCs, the contaminants would be effectively and permanently managed over the long term. LUCs and O&M would provide long-term effectiveness in eliminating future human and ecological receptor exposure to the contaminants left on-site by maintaining the cover (barrier), restricting residential development, and controlling construction and digging activities. Periodic LUCs/cover inspections and Five-Year Reviews would be conducted to evaluate the continued adequacy of the remedy.

4.2.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 3 would not include any active treatment technologies that would achieve reductions in the toxicity, mobility, or volume of contaminants in place at the site; however, prior to consolidating and covering contaminated soils under the soil cover to be constructed, lead stabilization treatment would be performed on any soils that are determined by waste characterization analysis to be hazardous by RCRA characteristic. Some reduction of PAH contaminant toxicity or volume might occur through natural attenuation processes, but this would not be monitored. The mobility of contaminants in the environment would be reduced by placement of contaminated material under the 2-foot soil cover, as well as by any potential chemical stabilization of lead soils to reduce the leaching of lead when under the on-site soil cover.

4.2.3.5 Short-Term Effectiveness

Alternative 3 would be effective in the short-term if the excavation, hauling, and grading work is done properly and with appropriate controls in place. Controls would be implemented to protect remediation construction workers, the public, and the environment until site restoration is completed. Implementation of Alternative 3 is not expected to pose any significant risks to the local community, workers, or the environment. Workers who implement Alternative 3 would be adequately safeguarded by implementation of a site-specific HASP and the use of PPE. OSHA standards would be followed during all remedial activities. Increased truck and heavy equipment vehicular traffic would occur during mobilization and demobilization, as well as importing clean fill and topsoil (e.g., 685 trucks for 15,100 tons backfill and topsoil for the excavated areas and the soil cover); however, while Alternative 3 includes hauling additional clean fill for the soil cover, it does not include the long-distance hauling traffic associated with off-site transport of waste materials like that of Alternative 2.

4.2.3.6 Implementability

Alternative 3 is readily implementable. No significant engineering, administrative, or construction difficulties are anticipated, although coordination with appropriate federal, state, and local agencies would be required. The labor, equipment, and materials necessary to implement this alternative are conventional and readily available. Multiple general and specialized contractors have the capability to perform the construction activities specified for this alternative. From a budgetary standpoint, unlike Alternative 2, which could be implemented in phases as budget allows, for Alternative 3 all capital would be needed to implement it during one construction mobilization to comply with ARARs.

Chemical stabilization (treatment) of lead soils has been widely tested and implemented at various remediation sites and is considered a reliable treatment technology for reducing the leachability of lead-contaminated soils. The RD/work plan would provide the specifications for excavation, treatment, on-site consolidation, construction of the soil cover, and site restoration. The necessary health and safety requirements for construction activities conducted as part of implementation of the remedy would be identified in the work plan. A traffic control plan would also be necessary due to the truck traffic to haul clean fill materials. No disposal facilities are included with this alternative; however, additional on-site hauling and grading is required for the soil cover. The administrative implementation would include the implementation of LUCs and the performance of inspections, O&M, and Five-Year Reviews.

Due to the presence of culturally sensitive areas within the AAs and TRZs, specific procedures will be implemented including notifying the VDHR and appropriate Native American tribes of any artifacts and/or human remains encountered during ground disturbance activities.

4.2.3.7 Cost

The capital cost for Alternative 3 is estimated to be $1,568,000. Future periodic costs for inspections, O&M, and Five-Year Reviews comprise: Quarterly LUC and soil cover inspections ($2,630 each including reporting) during the first 2 years and annually thereafter; $500 annual soil cover maintenance plus an estimated $8,000 every 5 years; and Five-Year Reviews estimated at $15,000 every 5 years. The PV of the future post-construction costs for Alternative 3—based on a 30-year period and a 0.4 percent real discount rate (OMB, 2019)—is estimated to be $233,000. Using the 30-year period, the total PV cost of Alternative 3 is $1,801,000. However, the long-term O&M and LUCs will continue in perpetuity. For perspective, the PV of the future post-construction costs for Alternative 3—based on a 100-year period and 0.4 percent discount rate—is estimated to be $648,000. Using the 100-year period, the more realistic total PV cost of Alternative 3 for comparison is $2,216,000. Quantity calculations are presented in Appendix B and a detailed cost estimate is provided in Appendix C.

Cost estimates for individual line items are based on quotations from potential vendors and subcontractors, engineering estimates, recent similar project experience, and published values (e.g., R.S. Means). If implemented, the actual cost of Alternative 3 would depend on the final scope and design parameters presented in the impending work plans, the schedule for implementation, competitive market conditions, actual scale weights of waste disposed, and other variables.

4.3 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

A comparative analysis is conducted to identify the advantages and disadvantages of each alternative relative to one another based on the threshold and balancing criteria. The analysis is summarized in Table 4-5 and discussed below.

4.3.1 Overall Protection of Human Health and the Environment

Alternative 1 (No Action) would not be protective of human health or the environment because no actions would be taken to prevent exposure or reduce or mitigate the unacceptable risks. Alternative 1 does not satisfy any RAOs.

Both Alternatives 2 (Excavation) and 3 (Soil Cover) would be more protective than Alternative 1. Alternatives 2 and 3 are comparable to each other in that they would both meet RAOs and be protective of human health and the environment. Under Alternative 2, the subject soils and sediment would be removed from the site and allow for UU/UE status. Under Alternative 3, the soils and sediment would remain on-site but under a soil cover barrier, which will require post-construction long-term controls (i.e., O&M and LUCs) to maintain protectiveness. UU/UE status cannot be attained with Alternative 3; Five-Year Reviews would be conducted to evaluate the protectiveness of Alternative 3.

4.3.2 Compliance with ARARs

Alternative 1 (No Action) would not comply with chemical-specific TBCs ARARs. No chemical- or location-specific ARARs apply to this alternative because no actions would be implemented.

Alternatives 2 (Excavation) and 3 (Soil Cover) would both meet chemical-specific, location-specific, and action-specific ARARs and TBCs, as evaluated in Tables 4-2, 4-3, and 4-4. Both require upfront tasks associated with working near sensitive ecological habitats or cultural resources at WFF (see Section 4.1). Alternative 3 requires long-term compliance tasks, whereas Alternative 2 allows for UU/UE.

4.3.3 Long-Term Effectiveness and Permanence

Alternative 1 (No Action) would not be effective or provide permanent protection from contaminants since no action would be taken. Alternative 2 (Excavation) would completely remove the contaminated soil and sediment that causes the human health and ecological risks. Alternative 3 (Soil Cover) would attain long-term effectiveness and permanence with sustained O&M of the soil cover and by implementing and enforcing the LUCs to prevent future unrestricted land uses. Alternative 3 would reduce the potential exposure to contaminated soil and sediment, but Alternative 2 will mitigate the site risk completely and allow for UU/UE. The protectiveness of Alternative 3 would be evaluated every 5 years.

4.3.4 Reduction in Toxicity, Mobility, or Volume Through Treatment

Alternative 1 (No Action) would not satisfy the statutory preference for treatment since no action would be performed. Under Alternative 2 (Excavation), all contaminated soils and sediment with concentrations greater than the PRGs would be permanently removed from the site. Lead- and lead shot-contaminated soils that exhibit the lead toxicity characteristic would be treated through chemical stabilization on-site prior to removal, which would significantly reduce the toxicity and mobility of lead-contaminated soils disposed of in a landfill. Alternative 3 (Soil Cover) consolidates the contaminated soil and sediment to one area of the site under a constructed soil cover. Lead stabilization treatment is also assumed for Alternative 3 to ensure the contaminated soil under the soil cover is not hazardous by characteristic. Also, the mobility and volume of contaminated soil and sediment may be reduced by the consolidation, incidental compaction, and cover. Lead leachability under natural on-site conditions is not considered problematic based on evaluation in the Site Investigation Report and reevaluation in the RI Report (Tetra Tech, 2009a and 2020).

4.3.5 Short-Term Effectiveness

No active response actions would be implemented under Alternative 1 (No Action); therefore, no additional short-term impacts at the site would be anticipated for this alternative. Alternatives 2 (Excavation) and 3 (Soil Cover) provide comparable short-term effectiveness. They both pose potential short-term safety risks to site workers due to earthwork construction activities. Alternative 2 includes 400 truckloads of excavated soils for off-site disposal. Both alternatives involve the import and placement of clean soil materials: Alternative 2 would require 400 truckloads of clean soil materials for backfilling/restoration and Alternative 3 would require 685 truckloads for backfilling/restoration and the soil cover. All workers would require training and medical monitoring in accordance with OSHA for both alternatives. Short-term risks to site workers would be mitigated using PPE, conventional dust suppression techniques, and site health and safety monitoring for both alternatives. The estimated construction duration for each of the alternatives is as follows:

- Alternative 1–No Action: No implementation,
- Alternative 2–Excavation and Off-Site Disposal: 3 months including off-site transportation and disposal.
- Alternative 3–Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs: 3 months including the implementation of LUCs. The first LUC inspection would occur 3 months after construction is completed (quarterly during first 2 years, then annually); however, O&M-related inspections would be more frequent to monitor for erosion and vegetation issues immediately following construction. Both LUCs and O&M would be maintained/performed in perpetuity as long as conditions do not allow for UU/UE.

4.3.6 Implementability

Alternative 1 (No Action) would be readily implementable because no remedial actions or measures would occur. Both Alternatives 2 (Excavation) and 3 (Soil Cover) would require coordination with several agencies, including with NOAA and the airfield operations prior to and during construction. Both alternatives require extensive E&S controls due to disturbing greater than 1 acre of land.

Alternative 2 is relatively easy to implement and involves standard construction techniques and equipment. There are ample companies with the trained personnel, equipment, and materials to perform site preparation and conduct soil excavation. There are several off-site landfills located within a reasonable distance from NASA WFF that accept nonhazardous CERLCA waste. Experienced HAZWOPER-certified workers and contracting companies are capable and readily available to excavate and transport the lead-, lead shot-, and PAH-contaminated soils to the appropriate disposal facility. Alternative 2 could include chemical stabilization of hazardous lead-contaminated soils prior to off-site transportation and disposal, but this technology has been widely tested and implemented at various remediation sites. The chemical stabilization reagents are typically proprietary but do not necessarily need to be applied by specialty subcontractors.

Alternative 3 is also relatively easy to implement using the same standard companies, construction techniques, and equipment as Alternative 2. Alternative 3 does not include off-site disposal of the excavated soil and sediment, but it does include the same assumed lead stabilization treatment to render any hazardous materials (by characteristic for lead) to be nonhazardous. It requires half the excavation as Alternative 2 (2,830 BCY versus 5,890 BCY) but almost double the imported backfill and topsoil due to the 2-foot soil cover (10,000 BCY versus 5,890 BCY). The long-term mission of NASA's airfield and NOAA's antennae facility could be affected by the 2-acre soil cover (e.g., if future expansion of the facility or airfield is needed). Also, long-term tasks (LUCs and O&M of soil cover) are required for Alternative 3 to maintain protectiveness, whereas UU/UE is achieved with Alternative 2. LUCs are easily implementable and LUC inspections and reporting are common tasks for many contractors. Regulatory personnel and environmental specialists are readily available to perform Five-Year Reviews.

No permits would be necessary from other agencies for Alternatives 2 and 3, because the CERCLA remedy would occur on-site. However, the substantive requirements of any applicable permits (e.g., E&S Control Plan and local construction permits) should be met.

4.3.7 Cost

The estimated capital and O&M and periodic costs associated with each alternative are provided in Table 4-5 and Appendix C. There are no costs associated with Alternative 1 (No Action) because no remedial actions or measures would occur. There are no recurring or future costs associated with Alternative 2 (Excavation), as it would permanently remove contaminated soils and sediment with concentrations greater than the PRGs from the site and allow for UU/UE. Alternative 3 (Soil Cover) has recurring future costs for O&M of the soil cover and maintaining LUCs (does not allow for UU/UE).

Alternative 2 is the most expensive alternative in capital because of the 8,830 tons of waste that is required for off-site disposal. Otherwise, on-site construction costs and duration are comparable between Alternatives 2 and 3. Both have virtually the same pre-construction efforts and cost, and both include assumed on-site treatment to stabilize lead in soil/sediment to render it nonhazardous. The estimated capital cost of the excavation and disposal under Alternative 2 is $2,386,000. There are no future costs for Alternative 2, so the PV of the total cost is the capital cost of $2,386,000.

The estimated capital cost of the excavation, consolidation, and construction of a soil cover under Alternative 3 is $1,568,000. The future O&M and monitoring (LUC inspections) costs of Alternative 3 would be $11,000 each of the first 2 years and then $3,100 annually thereafter; substantial soil cover maintenance every 5 years would be $8,000; and Five-Year Reviews would be $15,000 every 5 years. Considering the future costs, the PV of the total cost for Alternative 3 over a 30-year period using a 0.4 percent real discount rate is estimated to be $1,801,000 (see Table C2a in Appendix C). However, the O&M and LUC components extend in perpetuity for Alternative 3; therefore, for better comparison, the PV of the total cost over a 100-year period is estimated to be $2,216,000 (see Table C2b in Appendix C).

The chart shown below displays the cumulative non-discounted constant dollar cost over 100 years for Alternative 3 and the minor impact of discounting at the current OMB (2019) discount rate of 0.4 percent for projects lasting 30 years or more.

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TABLES

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TABLE 1-1
RECOMMENDED CLEANUP LEVELS FROM RI REPORT
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

Receptors (COC)	Recommended Cleanup Levels (1)(8)	
	Average (2)	*Not-To-Exceed / Maximum*
Plants (lead)	240 mg/kg	750 mg/kg
Birds (lead)	299 mg/kg	1,100 mg/kg
Birds (lead shot)	NA	100 LS/foot^2 (3)
Sediment Invertebrates (lead)	NA	530 mg/kg (4)
Human Health (lead)(5)	200 mg/kg	NA
Human Health (TCR for target PAHs)(6)	NA	1×10^{-4} ILCR (7)

Notes:
See Table 2-4 for selection of Preliminary Remediation Goals (PRGs) for this FS.
COC - Chemical of Concern
mg/kg - Milligram per kilogram
LS/foot^2 - Lead shot per square foot
NA - Not applicable
PAH - Polycyclic Aromatic Hydrocarbon
TCR - Target cancer risk
ILCR - Incremental Lifetime Cancer Risk

See sample and exceedance locations for each exposure area on Figures 1-3 through 1-6. The average lead concentration in surface and subsurface soil in the High Tower Range Exposure Area is below the average PRG of 200 mg/kg; however, individual concentrations in surface soil exceed 200 mg/kg and are shown for potential evaluation of hot spots. Lead shot above 100 LS/foot^2 in the High Tower Range Exposure Area encroaches into the western portion of the Northern Range Exposure Area. Samples in the Skeet Range Shooting Exposure Area were specific to PAH analysis; there is no unacceptable ecological risk from PAHs.

1. These recommended cleanup levels were developed in the Remedial Investigation (RI) Sampling and Analysis Plan (SAP) and the RI Report based on the evaluation of the risks to human health and ecological receptors (Tetra Tech, 2018a and 2020). See Appendix A of the 2018 SAP for the development of the ecological cleanup levels. These recommended values are used to facilitate data evaluation and discussion in the RI and the FS. They also are candidate preliminary remediation goals evaluated for selection in Table 2-4 of this FS.

2. Compared to the arithmetic mean concentration in respective depth interval in respective exposure area.

3. This value is applied to the surface and shallow subsurface soil (i.e., 0-6 and 6-12 inches). This was refined from 10 LS/foot^2 to 100 LS/foot^2 after the collection of additional sieve/lead shot counts and ingestion probability modeling in the Ecological Risk Assesment in the RI Report (Tetra Tech, 2020). The ingestion probability results are shown in Table 1-5.

4. Applies to the low-lying drainage area and palustrine forested wetland in the Northern Range Exposure Area.

5. Human health lead proposed cleanup level developed with IEUBK and Adult Lead Model methodology such that blood lead levels are less than 5 micrograms per deciliter in less than 5% of the population (children and the fetuses of pregnant workers).

6. Seven Target PAHs: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

7. Total point risk not to exceed TCR of 1×10^{-4} for the seven target PAHs (resulting in human health ILCR of 1×10^{-4}).

8. Derivation of recommended ecological cleanup levels (see Appendix A of the RI SAP and the ERA in the RI Report [Tetra Tech, 2018a and 2020]):

Terrestrial Plants

- 240 mg/kg average lead soil value for terresrial plants based on *2 times* the *USEPA Ecological Soil Screening Level*, which is expected to be less than the *lowest observed effect concentration (LOEC)*.

- 750 mg/kg maximum lead value for terrestrial plants based on *no observed effect concentration (NOEC)* for rye grass from Guy et al. (2004).

Birds

- 299 mg/kg average lead soil value for birds (American robin) is based on *food chain modeling*; it is the lead concentration associated with an *Ecological Effects Quotient (EEQ) of 1* based on the interpolation at *less than 1/3* the *lowest observed adverse effects level (LOAEL)* value.

- 1,100 mg/kg maximum lead soil value for birds (American robin) in soil is based on *food chain modeling*; it is the lead concentration associated with an *Ecological Effects Quotient (EEQ) of 1* based on the *LOAEL*-toxicity reference value.

- 100 LS/foot^2 maximum lead shot value for birds (mourning dove) based on *20 percent ingestion probability of one lead shot* using USEPA's suggested *ingestion model* from Bennet et al. (2011).

Sediment Invertebrates

- 530 mg/kg maximum lead sediment value for invertebrates is based on the *Washington State Sediment Management Standards sediment cleanup screening level* (Washington State Department of Ecology, 2013).

TABLE 1-2
COCs BY MEDIUM AND RECEPTOR
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

	Receptors						
	Human Health		Ecological				
Medium/ Chemical	Current/Future Industrial Workers	Future Hyptoethical Residents	Terrestrial Plants	Soil Invertebrates	Sediment Invertebrates	Birds	Mammals
HIGH TOWER RANGE EXPOSURE AREA							
Surface Soil							
Lead *	--	--	--	--	--	--	--
Lead Shot	--	--	--	--	--	**X**	--
Subsurface Soil							
Lead	--	--	--	--	--	--	--
NORTHERN RANGE EXPOSURE AREA							
Surface Soil							
Lead	**X**	**X**	**X**	**X**	**X**	**X**	--
Lead Shot **	--	--	--	--	--	--	--
Subsurface Soil							
Lead	--	**X**	--	--	--	--	--
SOUTHERN RANGE EXPOSURE AREA							
Surface Soil							
Lead	--	**X**	**X**	--	--	--	--
Lead Shot	--	--	--	--	--	**X**	--
Subsurface Soil							
Lead	--	--	--	--	--	--	--
SKEET RANGE SHOOTING EXPOSURE AREA							
Surface Soil							
Target PAHs	--	**X**	--	--	--	--	--
Lead Shot **	--	--	--	--	--	--	--
Subsurface Soil							
Target PAHs	--	**X**	--	--	--	--	--

Notes:
X - Chemical is retained as a risk-based Chemical of Concern (COC) to be addressed in the FS based on the risk assessments in and conclusions from the RI Report (Tetra Tech, 2020).
See sample locations and PRG exceedances for each exposure area on Figures 1-3 through 1-6.
* The area average for lead is below the human health PRG of 200 mg/kg. However, some individual concentrations in surface soil exceed 200 mg/kg.
Locations with concentrations above 200 mg/kg are indicated on Figures 1-3 through 1-6 for comprehensive review.
** Delineation of lead shot in the High Tower Range Area encroached into the western portion of the Northern Range Area. The Skeet Range Shooting Exposure Area is within the Southern Range Exposure Area, so lead shot encroaches into this area.
-- Samples in the Skeet Range Shooting Exposure Area were specific to PAH analysis; There is no unacceptable ecological risk associated with PAHs.
Seven Target PAHs for human health in this FS: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

TABLE 1-3
RESIDENTIAL HUMAN HEALTH RISK SUMMARY - SOUTHERN RANGE AND SKEET RANGE SHOOTING EXPOSURE AREAS
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

		Incremental Lifetime Cancer Risk (ILCR)		Estimated Non-Carcinogenic Hazard Index (HI)		
Chemical	**EPC (1) (mg/kg)**	**Residential RSL (2) (mg/kg)**	**Estimated ILCR**	**Primary Target Organ**	**Residential RSL (2) (mg/kg)**	**Estimated HI**
Surface Soil						
Benzo(a)anthracene	9.57	1.1	9E-06	NA	NA	--
Benzo(a)pyrene	9	0.11	8E-05	Developmental, Immune, Reproductive	18	0.5
Benzo(b)fluoranthene	12.4	1.1	1E-05	NA	NA	--
Benzo(k)fluoranthene	3.7	11	3E-07	NA	NA	--
Dibenzo(a,h)anthracene	4.55	0.11	4E-05	NA	NA	--
Indeno(1,2,3-cd)pyrene	7.3	1.1	7E-06	NA	NA	--
Lead (3)	190	NA	--	NA	400	--
		Total Cancer Risk	**2E-04**		**Total HI**	**0.50**
Subsurface Soil						
Benzo(a)anthracene	11.1	1.1	1E-05	NA	NA	--
Benzo(a)pyrene	9.78	0.11	9E-05	Developmental, Immune, Reproductive	18	0.5
Benzo(b)fluoranthene	13.9	1.1	1E-05	NA	NA	--
Dibenzo(a,h)anthracene	1.43	0.11	1E-05	NA	NA	--
Indeno(1,2,3-cd)pyrene	6.58	1.1	6E-06	NA	NA	--
Lead (3)	84.2	NA	--	NA	400	--
		Total Cancer Risk	**1E-04**		**Total HI**	**0.50**

Notes:
mg/kg- Milligram per kilogram   EPC - Exposure point concentration
RSL - Regional Screening Level   NA- Not applicable   ILCR - Incremental Lifetime Cancer Risk
ILCRs and HIs were calculated using a simple risk ratio technique, which divides the EPC by the RSL for residential exposure to soil and mulitiplies by the target risk level. For example, the ILCR for benzo(a)pyrene in surface soil was calculated as $(9.00 / 0.11) \times (1\times10^{-6}) = 8\times10^{-5}$.
The HI for benzo(a)pyrene was calculated as (9.00 / 18) × (1) = 0.5.
1. EPC is the 95% Upper Confidence Limit calculated by ProUCL Version 5.1.002.
2. USEPA RSL Table, November 2018. The non-carcinogenic values correspond to a target Hazard Quotient of 1. Carcinogenic values represent an ILCR of 1×10^{-6}.
3. Lead risks are evaluated separately using USEPA's Integrated Exposure Uptake Biokinetic (IEUBK) model and Adult Lead Model.

TABLE 1-4
INDUSTRIAL HUMAN HEALTH RISK SUMMARY - SOUTHERN RANGE AND SKEET RANGE SHOOTING EXPOSURE AREAS
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

Chemical	EPC (1) (mg/kg)	Incremental Lifetime Cancer Risk (ILCR)		Estimated Non-Carcinogenic Hazard Index (HI)		
		Industrial RSL (2) (mg/kg)	Estimated ILCR	Primary Target Organ	Industrial RSL (2) (mg/kg)	Estimated HI
Surface Soil						
Benzo(a)anthracene	9.57	21	5E-07	NA	NA	--
Benzo(a)pyrene	9	2.1	4E-06	Developmental, Immune, Reproductive	220	0.04
Benzo(b)fluoranthene	12.4	21	6E-07	NA	NA	--
Benzo(k)fluoranthene	3.7	210	2E-08	NA	NA	--
Dibenzo(a,h)anthracene	4.55	2.1	2E-06	NA	NA	--
Indeno(1,2,3-cd)pyrene	7.3	21	3E-07	NA	NA	--
Lead (3)	190	NA	--	NA	800	--
		Total Cancer Risk	**8E-06**		**Total HI**	**0.04**
Subsurface Soil						
Lead	84.2	NA	--	NA	800	--
Benzo(a)anthracene	11.1	21	5E-07	NA	NA	--
Benzo(a)pyrene	9.78	2.1	5E-06	Developmental, Immune, Reproductive	220	0.04
Benzo(b)fluoranthene	13.9	21	7E-07	NA	NA	--
Dibenzo(a,h)anthracene	1.43	2.1	7E-07	NA	NA	--
Indeno(1,2,3-cd)pyrene	6.58	21	3E-07	NA	NA	---
		Total Cancer Risk	**7E-06**		**Total HI**	**0.04**

Notes:
mg/kg- Milligram per kilogram	EPC - Exposure point concentration
RSL - Regional Screening Level	NA- Not applicable	ILCR - Incremental Lifetime Cancer Risk
ILCRs and HIs were calculated using a simple risk ratio technique, which divides the EPC by the RSL for residential exposure to soil and mulitiplies by the target risk level. For example, the ILCR for benzo(a)pyrene in surface soil was calculated as (9.00 / 0.11) × (1×10^{-6}) = 8×10^{-5}. The HI for benzo(a)pyrene was calculated as (9.00 / 18) × (1) = 0.5.
1. EPC is the 95% Upper Confidence Limit calculated by ProUCL Version 5.1.002.
2. USEPA RSL Table, November 2018. The non-carcinogenic values correspond to a target Hazard Quotient of 1. Carcinogenic values represent an ILCR of 1×10^{-6}.
3. Lead risks are evaluated separately using USEPA's Integrated Exposure Uptake Biokinetic (IEUBK) model and Adult Lead Model.

TABLE 1-5
LEAD SHOT INGESTION PROBABILITY
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

Sample	Adjusted[(1)] Total Lead Shot	#14 SIEVE		#20 SIEVE	
		Adjusted[(1)] Total Grit Sized Particles	Ingestion Probability[(2)]	Adjusted[(1)] Total Grit Sized Particles	Ingestion Probability[(2)]
HIGH TOWER RANGE AREA					
SR-SS-241-0006	3	870	0.01	18,431	0.00
SR-SS-320-0006	59	2,220	0.05	35,036	0.00
SR-SB-323-0006	94	2,323	0.08	41,328	0.00
SR-SS-332-0006	44	3,772	0.02	59,464	0.00
SR-SS-333-0006	9	4,031	0.00	69,931	0.00
SR-SS-334-0006	132	2,478	0.10	50,727	0.01
SR-SS-407-0006	94	709	0.24	--	--
SR-SS-407-0612	135	838	0.28	--	--
SR-SS-410-0006	179	3,149	0.11	--	--
SR-SS-410-0612	32	5,686	0.01	--	--
SR-SS-413-0006	35	770	0.09	--	--
SR-SS-417-0006	162	1,861	0.16	--	--
SR-SS-417-0612	109	3,413	0.06	--	--
SR-SS-418-0006	38	920	0.08	--	--
SOUTHERN RANGE AREA					
SR-SS-221-0006	151	1,118	0.24	33,575	0.01
SR-SS-221-0612	54	1,438	0.07	51,840	0.00
SR-SB-221-1224	25	275	0.17	9,125	0.01
SR-SS-225-0006	0	5,657	0.00	86,900	0.00
SR-SS-225-0612	8	3,408	0.00	56,686	0.00
SR-SS-238-0006	35	1,200	0.06	26,672	0.00
SR-SS-240-0006	241	1,993	0.22	29,800	0.02
SR-SS-309-0006	62	1,940	0.06	33,204	0.00
SR-SS-309-0612	6	1,394	0.01	31,532	0.00
SR-SS-312-0006	59	2,132	0.06	49,554	0.00
SR-SS-312-0612	15	2,093	0.01	55,742	0.00
SR-SS-316-0006	24	1,388	0.03	32,393	0.00
SR-SS-316-0612	12	2,102	0.01	42,712	0.00
SR-SS-328-0006	3	597	0.01	10,660	0.00
SR-SS-328-0612	0	614	0.00	11,390	0.00
SR-SS-331-0006	79	4,063	0.04	64,468	0.00
SR-SS-402-0006	132	1,079	0.22	--	--
SR-SS-403-0006	138	953	0.26	--	--
SR-SS-403-0612	47	1,020	0.09	--	--

Notes:
The probabilities were modeled in the Tetra Tech (2020) Remedial Investigation Report using EPA's / Bennett et al.'s (2011) Assessment of Methods for Estimating Risk to Birds from Ingestion of Contaminated Grit Particles.
1. Adjusted to a 1-foot by 1-foot by 6-inch volume (0.5 cubic feet).
2. Model for estimating probability of ingesting N lead particles by the mourning dove. Calculations are provided in Appendix H of the Tetra Tech (2020) Remedial Investigation Report.

TABLE 2-1
COCs AND PRG SELECTION
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

		Human Health PRGs[2]		Ecological PRGs[2]			Background Values[3]					
Medium[1]	**COCs**	**Residential**	**Industrial**	**Terrestrial Plants**	**Birds**	**Sediment Invetebrates**	**Molena Surface Soil**	**Molena Subsurface Soil**	**Bojak Surface Soil**	**Bojak Subsurface Soil**	**Selected PRG**	**Basis**
Surface Soil	Lead (*average*)[4] (mg/kg)	200	200	240	299	NA	30.6	16.4	21.1	13.3	200	Blood lead level < 5 µg/dL for residential child and fetus of pregnant adult worker
	Lead (*not-to-exceed*) (mg/kg)	NA	NA	750	1,100	NA	30.6	16.4	21.1	13.3	750	NOAEC for rye grass
	Lead Shot (*not-to-exceed*) ($LS/foot^2$)	NA	NA	NA	100	NA	NA	NA	NA	NA	100	Ingestion probability modeling for mourning dove
	Target PAHs (*TCR*)[5]	1×10^{-4}	NA	NA	NA	NA	NA	NA	NA	NA	1×10^{-4}	Residential ILCR < 1×10^{-4}
Subsurface Soil	Lead (*average*)[4] (mg/kg)	200	200	NA	NA	NA	30.6	16.4	21.1	13.3	200	Blood lead level < 5 µg/dL for residential child and fetus of pregnant adult worker
	Target PAHs (*TCR*)[5]	1×10^{-4}	NA	NA	NA	NA	NA	NA	NA	NA	1×10^{-4}	Residential ILCR < 1×10^{-4}
Sediment	Lead (*not-to-exceed*)[6] (mg/kg)	NA	NA	NA	NA	530	NA	NA	NA	NA	530	Washington State Sediment Management Standards sediment cleanup screening level

Notes
COC - Chemical of Concern
PRG - Preliminary Remediation Goal
NOAEC - No observed adverse effects concentration
mg/kg- milligrams per kilogram
NA - Not applicable
$LS/foot^2$ - Lead shot per square foot
PAH - Polycyclic aromatic hydrocarbon
TCR - Target cancer risk
ILCR - Incremental lifetime cancer risk

1. The surface soil and sediment media of concern addressed in the FS correspond to depth interval of 0 to 1 foot bgs. The subsurface soil medium of concern in the FS corresponds to a depth interval of 1 to 2 feet bgs.
2. See Table 1-1 for explanation of PRG candidates from the Tetra Tech (2020) Remedial Investigation (RI) Report. Also, see Appendix A of the Tetra Tech (2018a) Sampling and Analysis Plan for the RI.
3. Values for Molena and Bojak soils from Background Soil and Groundwater Investigation Report (Tetra Tech, 2004). Background data/values are being reevaluated separately at the time of this FS. Draft background values in December 2020 are 84.8 and 12.2 mg/kg for Molena surface and subsurface soils and 19.5 and 10.2 mg/kg for Bojak surface and subsurface soils, respectively.
4. Arithmetic mean lead concentration in the respective depth interval across the soil exposure unit (Northern Range, Southern Range, and High Tower Range Exposure Areas).
5. TCR not-to-exceed-PRG of 1×10^{-4} at any sample/location for the seven target PAH COCs: Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.
6. Sediment PRG applies to the palustrine forested wetland in the low-lying drainage area of the Northern Range Exposure Area. This value is more stringent than the 750 mg/kg value for surface and shallow subsurface soils throughout the site.

TABLE 3-1
PRELIMINARY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR SOIL
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
No Action	None	Not Applicable	No remedial actions taken.	Retained as baseline for comparison, as required by NCP.
Limited Action	Institutional Controls	Deed Restrictions (e.g., LUCs)	Administrative action is used to restrict future site activities within potentially contaminated area. Activities such as excavation or residential development could be restricted or prohibited.	Retained, in conjunction with additional controls and actions, to limit exposure to contaminated media.
		Local Ordinances	Administrative actions, such as zoning restrictions, are used to limit property use and activities.	Retained, in conjunction with additional controls and actions, to limit exposure to contaminated media. However, this site is on federal property and will remain under federal control for the foreseeable future.
	Access Restrictions	Physical Barriers	Fencing, markers, and warning signs to restrict site access and communicate hazards.	Retained, in conjunction with additional controls, to limit exposure to contaminated media.
	Monitoring	Groundwater Monitoring	Action to identify migration of COCs from impacted soils to groundwater so that other actions can be considered and implemented if necessary.	Eliminated because there are no risks from exposure to COCs in groundwater and leaching potential has been deemed negligible for future impacts. The final remedy would either remove, contain, or treat contaminated soil so that it would not migrate and pose any future threat to groundwater.
		Physical Inspections	Action to periodically check to ensure land uses have not changed over time, land alterations are not present, and property remains under NASA ownership.	Retained, in support of any remedy that leaves contaminants in place with or without cover systems.

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
Containment	Impermeable Cap	Engineered Cap	Use of low permeability geosynthetic barriers or asphalt/concrete (e.g., hard surface) cap to minimize exposure to contaminant soil and to minimize migration of contaminants to groundwater.	Eliminated because permeability does not need to be controlled for the COCs in this case. There are no risks from exposure to COCs in groundwater and leaching potential has been deemed negligible for future impacts.
	Permeable Cover	Soil Cover	Would prevent direct exposure to contaminated soils. Would minimize erosion and surface migration of contaminated soils.	Retained for further evaluation.
Removal	Excavation	Excavation	Means for removal of limited/localized or large areas of contaminated soil. This technology is coupled with disposal, treatment, or containment technologies to address the disposition of excavated material.	Retained to remove contaminated soil for off-site disposal or in conjunction with consolidation at the site under soil cover.
In Situ Treatment	Thermal	Vitrification/ Radiofrequency Heating	Use of high temperature to fuse inorganic contaminants into a glass matrix or the use of moderate temperature to volatilize contaminants and remove them from the vadose zone.	Eliminated due to the small volumes (depths) of COCs over a large area, as well as due to ineffectiveness and implementation concerns under shallow groundwater conditions.
	Physical/ Chemical	Soil Flushing	Use of water or solvents to remove contaminants from the vadose zone by leaching and collecting contaminated wastewater in the saturated zone followed by aboveground treatment.	Eliminated due to questionable effectiveness with a shallow groundwater table.

TABLE 3-1
PRELIMINARY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR SOIL
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
		Soil Vapor Extraction	Use of vacuum and possibly air sparging to volatilize and remove contaminants from the vadose zone.	Eliminated because the COCs are not volatile or have low volatilization rates.
		Solidification/ Stabilization	Use of pozzolanic materials to chemically fix inorganics and solidify the matrix to reduce leachability.	Retained, in conjunction with excavation option, due to potential need to minimize off-site disposal of hazardous waste (by characteristic for lead). Not considered for site-wide application to stabilize and leave in place.
Ex Situ Treatment	Physical/ Chemical	Soil Washing/ Solvent Extraction	Use of water and solvents to remove contaminants from solid materials.	Eliminated due to the complexity of the technology, and the presence of lead shot that will not be treated through this process.
		Solidification/ Stabilization	Use of pozzolanic materials to chemically fix inorganics and solidify the matrix to reduce leachability.	Retained, in conjunction with excavation option, due to potential need to minimize off-site disposal of hazardous waste (by characteristic for lead). Not considered for site-wide application to stabilize and leave in place.
	Biological	Landfarming	Tilling of contaminated soil in layers to remove VOCs and biodegrade organics.	Eliminated due to lack of effectiveness for metals COC (lead).
		Bioslurry Treatment	Treatment of soil in a slurry reactor under controlled conditions using natural or cultured microorganisms to biodegrade organics.	Eliminated due to lack of effectiveness for metals COC (lead).

TABLE 3-1
PRELIMINARY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR SOIL
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
	Thermal	Incineration	Use of high temperature to destroy organic contaminants. Process can be implemented both on- and off-site.	Eliminated due to lack of effectiveness for metals COC (lead).
		Low-Temperature Thermal Desorption	Use of low to moderate temperature to volatilize contaminants.	Eliminated due to low volatilization rates associated with metals COC (lead). PAH contamination accounts for less than 10% of the contaminated soils.
Disposal	Off-Site Disposal / Landfill	Permitted Treatment, Storage, and Disposal (TSD) Facility	Excavated soil is classified as hazardous waste or banned from land disposal. Disposal of contaminated soils at a permitted commercial TSD facility (i.e., hazardous waste landfill).	Eliminated. If needed, would address hazardous soils (characteristic for lead) with stabilization prior to off-site disposal.
		RCRA Subtitle D Solid Waste Disposal Facility	Excavated soil is classified as nonhazardous waste. Disposal of contaminated soils at an off-site permitted solid waste facility or industrial landfill.	Retained as disposal option for excavated soil. Anticipate addressing hazardous soils with stabilization, if needed, prior to off-site disposal.
		Consolidation	Excavation and placement in one location to minimize space and closure requirements.	Retained, in conjunction with on-site soil cover option.

Notes:
COC – Chemical of Concern
NCP – National Contingency Plan
PAH – Polycyclic aromatic hydrocarbon
LUC – Land use control
NASA – National Aeronautics and Space Administration

TABLE 3-2
RETAINED TECHNOLOGIES AND PROCESS OPTIONS FOR SOIL
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

General Response Action	Technology	Representative Process Option
No Action	None	Not Applicable
Limited Action	Land Use Controls (LUCs) (Institutional Controls)	Deed Restrictions and local ordinances
Containment Action	Permeable Cover	Soil Cover to Prevent Exposure (along with on-site consolidation)
Removal	Excavation	Excavation (for on-site consolidation or for off-site disposal)
Treatment	Physical/Chemical	Stabilization of contaminants (prior to off-site disposal, not to remain on-site)
Disposal	Off-Site Disposal	RCRA Subtitle D Solid Waste Disposal Facility (i.e., industrial landfill)

TABLE 4-1
DESCRIPTION OF FEASIBILITY STUDY ALTERNATIVES FOR SOIL
FEASIBILITY STUDY
SKEET RANGE MRS – FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

Soil Alternative Number	Alternative	Alternative Description
1	No Action	No remedial action in any sense will be implemented for soil at the site.
2	Excavation and Off-Site Disposal	• Cultural Resources Evaluation, Biological Evaluation, and substantive Wetland Permit requirements. Erosion and sediment control plan and implementation. • Pre-construction confirmation sampling to verify excavation limits. • Excavation of soil and sediment with lead concentrations or lead shot counts greater than PRGs to depth of 1 foot in the High Tower, Northern, and Southern Range Exposure Areas, as well as excavation of soil with PAH concentrations indicating risk above the PRG to depth of 1 foot in the Skeet Range Shooting Exposure Area. • Clean backfill of excavated areas. Revegetate/seed upland areas and low-lying drainage area, as well as limited restoration of impacted portion of palustrine forested wetland. • Pre-construction waste characterization sampling for off-site disposal. o Based on site concentrations and previous waste characterization results, assume 25% of the lead- and lead shot-contaminated soil will be hazardous by RCRA characteristic for lead (i.e., TCLP lead concentration > 5 mg/L). Perform chemical lead stabilization treatment on-site with phosphate reagent—under USEPA's (1998) AOC Policy—mixing to convert leachable lead into insoluble minerals and mixed mineral forms within the matrix, allowing for nonhazardous waste transportation and off-site disposal. o The remaining 75% of excavated material is assumed to be nonhazardous and would not require lead stabilization. • Transportation of excavated soils (portions treated if needed to attain nonhazardous characterization) for appropriate off-site disposal. • Overall site restoration.
3	Excavation, On-Site Consolidation under Soil Cover, and Land Use Controls (LUCs)	• Cultural Resources Evaluation, Biological Evaluation, and substantive Wetland Permit requirements. Erosion and sediment control plan and implementation. • Pre-construction confirmation sampling to verify excavation limits. Waste characterization for excavated soils to be consolidated on-site, if required. • Excavation of soil with lead shot counts greater than the PRG to a depth of 1 foot in the High Tower Range Exposure Area; soil and sediment with lead concentrations greater than PRGs to a

Soil Alternative Number	Alternative	Alternative Description
		depth of 1 foot in the Northern Range Exposure Area; and soil with PAH concentrations indicating risk above the PRG to a depth of 1 foot in the Skeet Range Shooting Exposure Area; and isolated soils with lead concentrations and lead shot counts above PRGs in Southern Range Exposure Area for consolidation with other excavated soils under a soil cover—to be located on the larger soil Attainment Area in the Southern Range Exposure Area. o Consolidate and spread excavated soils and sediments to 1-foot-thick layer over an area of approximately 2 acres in the Southern Range Exposure Area. o Cover consolidated soils and sediments with 2-foot-thick soil cover in accordance with applicable or ARARs. • Pre-construction waste characterization sampling for on-site consolidation and covering in-place. o Even though soils will be left and covered on-site, assume same as Alternative 2: 25% of the lead- and lead shot-contaminated soil will be hazardous by RCRA characteristic for lead (i.e., TCLP lead concentration > 5 mg/L). Perform same chemical lead stabilization treatment on-site with phosphate reagent mixing—under USEPA's (1998) AOC Policy—to convert leachable lead into insoluble minerals and mixed mineral forms within the matrix, allowing for ensured nonhazardous contaminated soil/sediment waste consolidation on top of nonhazardous in situ contaminated waste soils to be covered. o The remaining 75% of excavated material is assumed to be nonhazardous and would not require lead stabilization. • Clean backfill of excavated areas. Revegetate/seed upland areas and low-lying drainage area, as well as limited restoration of impacted portion of palustrine forested wetland. • Long-term O&M for soil cover integrity and LUCs to prevent non-industrial use and intrusive activities through the cover. o LUCs will be established, maintained, and inspected periodically for the covered area to ensure integrity of the exposure barrier (to prevent human health and ecological exposure to lead, lead shot, and PAH-contaminated soils above the PRGs). o LUCs include establishment in the facility work/safety permit system, as well as annual site inspections and annual LUC inspection reports. o O&M includes periodic soil cover repairs due to, e.g., erosion or animal burrows.

TABLE 4-1
DESCRIPTION OF FEASIBILITY STUDY ALTERNATIVES FOR SOIL
FEASIBILITY STUDY
SKEET RANGE MRS – FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

Soil Alternative Number	Alternative	Alternative Description
		o If ownership of the base is transferred, with contamination remaining in place, Environmental Land Use Restrictions (ELURs) will be recorded in accordance with applicable laws and the requirements of the LUC Remedial Design. • Overall site restoration. • Includes Five-Year Reviews for contamination remaining on-site above PRGs.

Notes:
AOC – Area of Contamination
ARAR – Applicable or Relevant and Appropriate Requirement
LUC – Land use control
O&M – Operation and maintenance
PAH – Polycyclic aromatic hydrocarbon
PRG – Preliminary remediation goal
RCRA – Resource Conservation and Recovery Act
TCLP – Toxicity Characteristic Leaching Procedure

TABLE 4-2
ANALYSIS OF CHEMICAL-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

Requirement	Citation	Status	Synopsis of Requirement	Compliance Actions
Federal				
USEPA Human Health Assessment Cancer Slope Factors (CSFs)	None	TBC for Alternatives 1, 2, and 3	Guidance values used to evaluate the potential carcinogenic hazards caused by exposure to contaminants.	Human health risks from exposure to PAHs, as assessed with CSFs, are used to evaluate exposures to carcinogenic contaminants in site media and, in this case, develop site-specific target-cancer-risk-based PRGs. The limits of the PAH-related Attainment Areas (AA)s and Target Remediation Zones (TRZs) for both Alternatives 2 and 3 are based calculated risk exceedances of the target-cancer-risk-based-PRG of 1×10^{-4} for the seven target PAHs at a sample locations during the Remedial Investigation[(1)] (also see Table 2-1 and Figures 2-2, 4-1, and 4-2). Benzo(a)pyrene, one of the seven target PAHs, also has non-cancer toxic effects, but they are below the threshold requiring action (i.e., calculated Hazard Index is less than 1); addressing benzo(a)pyrene based on risk levels determined using its CSF is more conservative in this case. Alternative 1–No action would not comply with this TBC as no actions or efforts would be taken to address PAHs to meet the risk-based cleanup level or to monitor their concentrations and associated risks.

Requirement	Citation	Status	Synopsis of Requirement	Compliance Actions
USEPA Guidance Document(s) on human health protective levels for lead in soil and in the blood.	USEPA (1994a, 1994b, 2003, 2007, 2010, 2016, 2017a, and 2017b)	TBC for Alternatives 1, 2, and 3	USEPA guidance documents and advisories for evaluating risks to adults and children posed by lead in soil.	Risks from lead assessed under these guidance documents will be addressed through remediation measures. The average-PRG of 200 mg/kg is developed with USEPA's IEUBK and Adult Lead Model methodology such that blood lead levels are less than the most recently (2017a and 2017b) recommended 5 µg/dL in less than 5% of the population (children and the fetuses of pregnant workers) (see Sections 1.6 and 2.4 and Tables 1-1 and 2-1). The limits of the lead-related AAs/TRZs for Alternatives 2 and 3 (see Figures 2-2, 4-1, and 4-2) are based on addressing lead concentrations in each exposure area such that the remaining average lead concentrations is less than 200 mg/kg. This human health lead PRG is more conservative than the ecological lead PRG candidates (see Table 2-1). Alternative 1–No action would not comply with this TBC as no actions or efforts would be taken to address lead to meet the cleanup levels or to monitor their concentrations and associated toxic effects to human receptors.

Requirement	Citation	Status	Synopsis of Requirement	Compliance Actions
USEPA Ecological Soil Screening Level (SSL) literature-based study benchmarks and values (e.g., LOEC and LOAEL)	USEPA (2020), Guy et al. (2004), Washington State Department of Ecology (2013)	TBC for Alternatives 1, 2, and 3	Guidance and empirically-based literature values and processes used to evaluate risks to ecological receptors caused by exposure to contaminants.	Ecological SSLs and other literature-based values and food chain models are used to evaluate exposure risks from lead to terrestrial plants, soil invertebrates, sediment invertebrates, insectivorous birds and mammals, and herbivorous birds and mammals. Several PRG candidates for lead are developed for each receptor in soil or sediment based on various values, including average- and not-to-exceed-PRGs (see Section 1.7 and Table 2-1). Soil or dry sediment in the low-lying drainage area and palustrine forested wetland in the Northern Range Exposure Area was evaluated as sediment in the ERA. Alternative 1–No action would not comply with this TBC as no actions or efforts would be taken to address lead to meet the cleanup levels or to monitor their concentrations and associated toxic effects to ecological receptors.

Requirement	Citation	Status	Synopsis of Requirement	Compliance Actions
Ecological lead shot ingestion probability modeling	USEPA-recommended Bennett et al. (2011) model	TBC for Alternatives 2 and 3	Guidance and probability model used to evaluate risks to birds from ingesting grit and lead shot.	Ingestion probability modeling was used to evaluate risks to birds and to develop the lead shot PRG for soil. Modeling was performed with USEPA-recommended Bennett et al.'s (2011) ingestion probability model using the lead shot count and soil sieve results (see Table 1-5). Because the habitat (i.e., High Tower Range and Southern Range Exposure Areas for lead shot) is not a wildlife refuge or other type of sensitive environment, a probability of 20% that a bird would ingest one lead shot was the basis of the recommended lead shot PRG of 100 lead shot per square foot (LS/ft^2) developed during the Remedial Investigation (RI) (Tetra Tech, 2018a and 2020) (see Tables 1-1 and 2-1). The probability modeling was conducted for all three ecological depth intervals (i.e., 0-6, 6-12, and 12-24 inches) to determine unacceptable risks to birds in the Ecological Risk Assessment (ERA) during the RI, although the primary lead shot exposure for birds would be in the top 6 inches. Based on the modeling results, the lead shot PRG is applied to the 0- to 1-foot depth interval for the lead-shot-related AAs/TRZs in the High Tower and Southern Range Exposure Areas as shown on Figures 2-2, 4-1, and 4-2.
State				
There are no Commonwealth of Virginia chemical-specific ARARs for the alternatives under evaluation.				

Notes:
ARAR – Applicable or Relevant and Appropriate Requirement
USEPA – United States Environmental Protection Agency
mg/kg – Milligrams per kilogram
LOEC – Lowest observed effect concentration
TBC – To be considered
IEUBK - Integrated Exposure Uptake Biokinetic [Model]
μg/dL – Micrograms per deciliter
LOAEL – Lowest observed adverse effects level

TABLE 4-2
ANALYSIS OF CHEMICAL-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

NASA – National Aeronautics and Space Administration
PAH – Polycyclic aromatic hydrocarbon
SSL – Soil Screening Level
PRG – Preliminary Remediation Goal

1. Seven Target PAHs: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

Human Health Risk / Lead ARAR Citations:

USEPA, 1994a. Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities. OSWER Directive 9355.4-12. Office of Emergency and Remedial Response. Washington, DC. July 14.

USEPA, 1994b. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children. USEPA/540/R-93/081. Office of Emergency and Remedial Response. Washington, DC. February.

USEPA, 2003. Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil. EPA-540-R-03-001. December 1996 finalized January.

USEPA, 2007. Guidance for Developing Ecological Soil Screening Level, Attachment 4-1, Exposure Factors and Bioaccumulation Models for Derivation of Wildlife Eco-SSLs. Office of Solid Waste and Emergency and Response. OSWER Directive 9285.7-55. April.

USEPA, 2010. Integrated Exposure Uptake Biokinetic Model for Lead in Children, Windows® version (IEUBKwin v 1.1 Build 11). February.

USEPA, 2016. Updated Scientific Considerations for Lead in Soil Cleanups. OLEM Directive 9200.2-167. Office of Land and Emergency Management. Washington, DC. December 22.

USEPA, 2017a. Update to the Adult Lead Methodology’s Default Baseline Blood Lead Concentration and Geometric Standard Deviation Parameters. OLEM Directive 9285.6-56. Office of Land Emergency Management. Washington, D.C. May.

USEPA, 2017b. Recommendations for Default Age Range in the IEUBK Model. OLEM Directive 9200.2-177. Office of Land Emergency Management. Washington, D.C. November.

Ecological Risk / Lead and Lead Shot Citations.

USEPA, 2020. Ecological Soil Screening Level (Eco-SSL) Guidance and Documents at https://www.epa.gov/risk/ecological-soil-screening-level-eco-ssl-guidance-and-documents and literature values https://www.epa.gov/chemical-research/ecological-soil-screening-level.

Guy, C., Huston, M, Krest, S., and D. Murphy. 2004. Ecological Risk Assessment for the Prime Hook National Wildlife Refuge Lead Shot Site, Milton, Delaware. U.S. Fish and Wildlife Service, Chesapeake Field Office, Annapolis, MD. CBFO-C03-04. August.

Bennett, R., D. Hoff and M. Etterson, 2011. Assessment of Methods for Estimating Risk to Birds from Ingestion of Contaminated Grit Particles. U.S. Environmental Protection Agency, Ecological Risk Assessment Support Center, Cincinnati, OH. EPA/600/R-11/023.

Washington State Department of Ecology. 2013. Sediment Management Standards, Chapter 173-204 WAC. Publication No. 13-09-055. September.

Requirement	Citation	Status	Synopsis of Requirement	Compliance Action
Federal				
National Historic Preservation Act (NHPA)	36 CFR Part 800	Applicable to Alternatives 2 and 3	Requires federal agencies to consider the effects of their actions on historic properties before undertaking a project. Federal agencies are required to initiate consultation with the State Historic Preservation Office (SHPO) informing them of the planned action and requesting their submittal of any comments or concerns.	If *Potential* or *Eligible* areas of effect are identified during the desktop-like study (compliant with the NHPA), then the project may proceed by either 1.) conducting a Phase 1 archeological survey (background research, visual assessment/site walkover, and subsurface archeological excavations) before clearing and excavation work begins, submitting a Phase 1 Report to VDHR, and getting VDHR approval; or 2.) having on-site archaeological support during clearing and excavations and producing an archaeological sensitive assessment deliverable after construction. NASA will coordinate with VDHR and appropriate Native American tribes. VDHR and appropriate Native American tribes will be notified of any artifacts and/or human remains encountered during ground disturbance activities. There are no other ARARs associated with the culturally sensitive areas at the Skeet Range MRS.

TABLE 4-3
ANALYSIS OF LOCATION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

Requirement	Citation	Status	Synopsis of Requirement	Compliance Action
Endangered Species Act (ESA) of 1973	Section 7(a)(2) of ESA; 50 CFR 17.21 and 17.31; 50 CFR 402.12	Applicable to Alternatives 2 and 3	This act requires federal agencies to act to avoid undertaking, funding, permitting or authorizing actions that are likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat in the construction "Action Area." A biological assessment shall evaluate the potential effects of the action on listed and proposed species and designated and proposed critical habitat and determine whether any such species or habitat are likely to be adversely affected by the action and is used in determining whether formal consultation or a conference is necessary.	A review of the available information indicates several possible state or federally listed endangered or threatened species that may permanently or seasonally reside in portions of the Skeet Range MRS. While the habitat-assessment-site-visit during the RI did not observe any, a Biological Evaluation (or biological opinion) will be prepared and submitted to USFWS for review for the anticipated Action Area. Continual observations also would occur throughout the remedial action under any of the alternatives.
Coastal Zone Management Act	15 CFR 923.53	Applicable to Alternatives 2 and 3	This act requires federal agencies to ensure that, if a "Proposed Action" will have reasonably foreseeable effects on coastal resources, then the action must be consistent with the state's coastal zone management program.	Activities for both Alternatives 2 and 3 are within Virginia's Coastal Zone. NASA will review which enforceable policies [of Virginia's NOAA-approved Coastal Zone Management Program] apply based on a review of the Proposed Action's effects on coastal zone uses and resources. This is partially reliant on the results of the Biological Evaluation (see above).

TABLE 4-3
ANALYSIS OF LOCATION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

Requirement	Citation	Status	Synopsis of Requirement	Compliance Action
Fish and Wildlife Coordination Act	16 United States Code (USC) 661-663	Applicable to Alternatives 2 and 3	Requires that the USFWS, National Marine Fisheries Service, and related state agencies be consulted prior to structural modification of any body of water, including wetlands. If modifications must be conducted, the regulation requires that adequate protection be provided for fish and wildlife resources.	This regulation will serve as guidance during the excavation in the High Tower and Northern Range Exposure Areas (see Figures 2-2, 4-1, and 4-2): TRZ LS1 uphill from the wetland drainage area, TRZ L1 soil in the upland drainage area, and TRZ L1 Sediment in the palustrine forested wetland habitat. Appropriate erosion and sediment (E&S) control measures and spill prevention measures will be implemented under Alternatives 2 and 3.
Protection of Wetlands	Executive Order (EO)11990	TBC for Alternatives 2 and 3	EO 11990 requires that for all projects, all agencies shall take action to minimize the destruction, loss, or degradation of wetlands. The project must include all practicable measures to minimize harm to wetlands	This EO will serve as guidance during the excavation in the Northern Range Exposure Area under Alternatives 2 and 3 (see Figures 2-2, 4-1, and 4-2): TRZ L1 Sediment is the 1,700-square foot (0.04-acre) soil/sediment area to be excavated from the palustrine forested wetland habitat. The area will be backfilled with loamy fill and likely allowed to revegetate naturally. No net loss of habitat.
Floodplain Management	Executive Order 11988	Applicable to Alternatives 2 and 3	Executive Order 11988 requires that projects avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains.	The northern part of the Skeet Range MRS is in a flood zone. After the excavation in the Northern Range Exposure Area under both Alternatives 2 and 3, site restoration activities would be conducted to restore and preserve the flood plains.

Requirement	Citation	Status	Synopsis of Requirement	Compliance Action
Discharge of Dredged or Fill Material into Waters of the United States, Clean Water Act (CWA) Part 404(b)(1)	40 CFR 230.10 (Restrictions on Discharge), 230.41 (Wetlands), 230.93 (General Compensatory Mitigation Requirements),	Applicable to Alternatives 2 and 3	During the identification, screening, and evaluation of alternatives, the effects on wetlands will be evaluated. Adverse impacts on wetlands will be avoided if possible. No activity that adversely affects a wetland shall be permitted if a practicable alternative that has less effect is available. If there is no other practicable alternative, impacts must be mitigated.	USACE or designee will be consulted regarded any actions that affect wetlands. The 1,700-square foot (0.04-acre) portion of palustrine forested wetland to be impacted by excavation under both Alternatives 2 and 3 is part of a presumably jurisdictional wetland based on the evaluation performed during the Remedial Investigation (Tetra Tech, 2020). USACE will be consulted prior to any remedial action. No net loss of habitat.
State				
Coastal Zone Management	Virginia Coastal Zone Management Program	Applicable to Alternatives 2 and 3	Virginia's federally approved Coastal Zone Management Program authorizes VDEQ to require that coastal zone actions are consistent with state laws and enforceable policies.	See above for the federal Coastal Zone Management Act ARAR discussion. Activities for both Alternatives 2 and 3 are within Virginia's Coastal Management Zone. NASA will ensure that any Proposed Action's effects on coastal zone uses and resources will be consistent with Virginia Coastal Zone Management Program's enforceable policies.

Requirement	Citation	Status	Synopsis of Requirement	Compliance Action
Wetlands Mitigation–Compensation Policy	4 VAC 20-390	Applicable to Alternatives 2 and 3	This policy encourages, where appropriate, the compensation of all permitted tidal wetland losses, especially vegetated losses, provided all mitigative measures have been considered to avoid any impact. This should include compensation on-site, compensation within the watershed, compensation through the use of a mitigation bank, or payment to an in-lieu fee account.	Excavation in the drainage area in the Northern Range Exposure Area under Alternatives 2 and 3 (see Figures 2-2, 4-1, and 4-2) will temporarily impact a 1,700-square foot (0.04-acre) portion of the palustrine forested wetland habitat. The area will be backfilled with loamy fill and likely allowed to revegetate naturally. No net loss of habitat.
Wetlands Policy	9 VAC 25-380	Applicable to Alternatives 2 and 3	These regulations contain procedures and restrictions for siting water treatment plants, controlling construction activities, and controlling non-point sources to prevent discharges which will impair the quality of a wetland area. Alteration in quantity or quality of the natural flow of water, which nourishes the ecosystem, should be minimized.	A 1,700-square foot (0.04-acre) portion of the palustrine forested wetland habitat would be impacted temporarily during sediment excavation in TRZ L1 Sediment in the Northern Range Exposure Area under both Alternatives 2 and 3. Appropriate E&S controls will be used during construction activities and removed when restoration metrics are met.
Water Resources Policy	9 VAC 25-390	Applicable to Alternatives 2 and 3	This policy restricts construction in floodplains, and requires minimizing the destruction, loss, or degradation of wetlands and surface water resources to assure water quality and quantity (i.e., Virginia's water resources) needs are always met.	A 1,700-square foot (0.04-acre) portion of the palustrine forested wetland habitat would be impacted temporarily during sediment excavation in TRZ L1 Sediment in the Northern Range Exposure Area under both Alternatives 2 and 3. The area will be backfilled with loamy fill and likely allowed to revegetate naturally.

TABLE 4-3
ANALYSIS OF LOCATION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

Requirement	Citation	Status	Synopsis of Requirement	Compliance Action
Endangered and Threatened Species	4 VAC 15-20-130	Applicable to Alternatives 2 and 3	These regulations from the Department of Game and Inland Fisheries prohibit the taking of endangered species. The cited regulations provide listings of endangered species and definitions of actions which constitute taking.	A review of the available information indicates several possible state or federally listed endangered or threatened species that may permanently or seasonally reside in portions of the Skeet Range MRS. While the habitat-assessment-site-visit during the RI did not observe any, a biological opinion will be prepared and submitted under the federal regulation to the regional USFWS for review for the anticipated Action Area due to working in and near the wetland and forested areas under both Alternatives 2 and 3. Continual observations also would occur throughout the remedial action under any of the alternatives.
Endangered Plant and Insect Species Act Regulations	2 VAC 5-320	Applicable to Alternatives 2 and 3	These regulations from the Virginia Department of Game and Inland Fisheries prohibit the taking of endangered plant and insect species.	A review of the available information does not indicate any state listed endangered or threatened plant and insect species at the Skeet Range MRS. While the habitat-assessment-site-visit during the RI did not observe any, the federal biological opinion referenced above will further evaluate their presence. Continual observations also would occur throughout the remedial action under any of the alternatives.

TABLE 4-3
ANALYSIS OF LOCATION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

Notes:
ARAR – Applicable or Relevant and Appropriate Requirement
CFR – Code of Federal Regulations
USFWS – United States Fish and Wildlife Service
NASA – National Aeronautics and Space Administration
VDEQ – Virginia Department of Environmental Quality
TBC – To be considered
VAC – Virginia Administrative Code
USACE – United State Army Corps of Engineers
NOAA – National Oceanic and Atmospheric Administration

TABLE 4-4
ANALYSIS OF ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

Requirement	Citation	Status	Synopsis of Requirement	Compliance Action
Federal				
Clean Water Act - National Pollutant Discharge Elimination System (NPDES)	40 CFR 122.26	Relevant and Appropriate for Alternatives 2 and 3	Runoff quality and sediment discharges from construction projects with earth disturbance must be controlled.	No intentional discharge to surface water bodies will take place under Alternative 2 or Alternative 3 at the Skeet Range Munitions Response Site (MRS). An erosion and sediment (E&S) control plan will be implemented and adhered to during all excavation activities to mitigate risks from surface water runoff and work within and near the palustrine forested wetland. These requirements will be met by following the substantive requirements of a NPDES Stormwater construction permit. Disturbances greater than or equal to 5 acres are classified as Large, and disturbances less than 5 acres (Alternatives 2 and 3) are classified as Small. Virginia is an NPDES-authorized state, so Virginia's rules would be used. The E&S controls will not be removed until permanent controls (revegetation) are established.
RCRA Regulations, Hazardous Waste Determination	40 CFR Part 262.11 (a) through (e)	Applicable to Alternatives 2 and 3	Defines method to determine if a solid waste is a hazardous waste. Virginia is a RCRA-authorized state and incorporates the federal regulations (with some revisions) by reference. The federal regulations are listed here for clarity.	Pre-construction TCLP samples will be collected for waste characterization to determine appropriate lead treatment prior to covering on-site (Alternative 3) or off-site transportation and disposal (Alternative 2). The on-site lead leachability treatment component (if needed) would stabilize lead in soils and render the material nonhazardous by characteristic, and, hence, allow for placement on-site under a soil cover (Alternative 3) or nonhazardous off-site transportation and disposal. TCLP samples would be collected after treatment to confirm the nonhazardous characteristic for lead has been achieved.

Requirement	Citation	Status	Synopsis of Requirement	Compliance Action
Management of Remediation Waste Under RCRA – Area of Contamination (AOC) Policy	USEPA 530-F-98-026 (October 1998)	TBC for Alternatives 2 and 3	This policy describes how remediation wastes can be handled and treated on-site without triggering other RCRA ARARs.	The AOC policy allows wastes to be consolidated or treated within an AOC (i.e., site) without triggering land disposal restrictions or minimum technology requirements. Lead-contaminated soils can be treated in situ or in staged areas within the site (if needed) prior to covering (Alternative 3) or off-site transportation and disposal as nonhazardous waste (Alternative 2).
Subtitle D Solid Waste Landfills – Final Cover	40 CFR 258.60 (a), (b), and (c)	Relevant and Appropriate for Alternative 3	Establishes design and operating criteria for solid waste [nonhazardous] landfills.	The closure and post-closure care requirements under RCRA Subtitle D may be relevant and appropriate for Alternative 3 within the limits of site. The covering of in situ contamination and consolidated excavated contamination with a vegetative soil cover requires post-construction periodic O&M and LUC inspections. These requirements are intended to minimize the infiltration of water into the landfill and maintain the integrity of the cover during the post-closure care period by minimizing cover erosion. Minimum requirements for a final landfill cover are included; however, states with USEPA-approved programs may approve alternate cover designs. Post-closure care must be conducted for 30 years; however, states with USEPA-approved programs have the authority to lengthen or shorten the post-closure period.
State				
Virginia Waste Management Act and Solid Waste Management Regulation	9 VAC 20-81-160 (D)(2)(a), (c), and (f) and (D)(3)	Relevant and Appropriate for Alternative 3	These regulations describe the final cover for a solid waste disposal facility.	These requirements would be relevant and appropriate for site closure and post-closure care under Alternative 3, which would involve consolidating and covering contaminated soil with a vegetative soil cover, requiring post-construction periodic O&M and LUC inspections.

Requirement	Citation	Status	Synopsis of Requirement	Compliance Action
Virginia Hazardous Waste Determination	9 VAC 20-60-262 (refer to Federal regulation above)	Applicable to Alternatives 2 and 3	Defines method to determine if a solid waste is a hazardous waste.	Pre-construction TCLP samples will be collected for waste characterization to determine appropriate lead treatment prior to covering on-site (Alternative 3) or off-site transportation and disposal (Alternative 2). The on-site lead leachability treatment component (if needed) would stabilize lead in soils and render the material nonhazardous by characteristic, and, hence, allow for placement on-site under a soil cover (Alternative 3) or nonhazardous off-site transportation and disposal. TCLP samples would be collected after treatment to confirm the nonhazardous characteristic for lead has been achieved.
Virginia Erosion and Sediment Control Act Regulations	9 VAC 25-840-10 through -65, and -80	Applicable to Alternatives 2 and 3	Establishes requirements for erosion control to protect of the surface water of the state.	An E&S control plan will be implemented and adhered to during all construction activities under either of Alternatives 2 or 3.
Virginia General VPDES Permit for Discharge of Stormwater from Construction Activities	9 VAC 25-880	Applicable to Alternatives 2 and 3	Regulates quality of point-source stormwater discharges from small and large construction site.	Point source stormwater discharges from the site activities would meet the substantive requirements of this general permit.

TABLE 4-4
ANALYSIS OF ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

Requirement	Citation	Status	Synopsis of Requirement	Compliance Action
Virginia Standards of Performance for Visible Emission and Fugitive Dust	9 VAC 5-50-90	Applicable to Alternatives 2 and 3	Establishes standards to minimize or prevent fugitive dusts from stationary sources, including the construction of the stationary sources or any other building, structure, facility, or installation.	If sustained visible dust emissions are observed during the implementation of Alternatives 2 or 3, then NASA will control these releases by reducing dust generation operations and/or hydrating the materials. Reasonable precautions (best management practices) will be taken to prevent particulate matter from becoming airborne during construction activities. These will be detailed in the Remedial Design or Remedial Action Work Plan, such as the following: Application of water to roads, materials, and stockpiles; covering open-bodied vehicles that are transporting materials or soil likely to create dust; and maintenance of roadways including the removal of soil that has been tracked out by equipment.

Notes:
ARAR – Applicable or Relevant and Appropriate Requirement
CFR – Code of Federal Regulations
USEPA – United States Environmental Protection Agency
O&M – Operation and maintenance
RCRA – Resource Conservation and Recovery Act
TBC – To be considered
VAC – Virginia Administrative Code
NASA – National Aeronautics and Space Administration
LUC – Land use control
TCLP – Toxicity Characteristic Leaching Procedure

TABLE 4-5
SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

NCP Criterion	Alternative 1 No Action	Alternative 2 Excavation and Off-Site Disposal	Alternative 3 Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT			
Protection of Human Health and the Environment	Does not meet the RAOs. No reduction of identified unacceptable risks and no protection of human health and the environment.	Removing the contaminated soil and sediment meets the RAOs and avoids future actions or controls for the protection of human health and the environment.	Meets the RAOs for the protection of human health and the environment by preventing exposure to contaminated soil and sediment. The soil cover would be a barrier to contamination for industrial workers and ecological receptors; O&M would monitor and maintain the cover integrity. LUCs would prevent residential development (and, hence, residential exposure) and control intrusive activities.
COMPLIANCE WITH ARARs			
Chemical-Specific ARARs	Would not comply.	Would comply with ARARs.	Would comply with ARARs.
Location-Specific ARARs	Not applicable.	Would comply with ARARs.	Would comply with ARARs.
Action-Specific ARARs	Not applicable.	Would comply with ARARs.	Would comply with ARARs.

NCP Criterion	Alternative 1 No Action	Alternative 2 Excavation and Off-Site Disposal	Alternative 3 Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
LONG-TERM EFFECTIVENESS AND PERMANENCE			
Magnitude of Residual Risk	Existing risks would remain.	Risks at the site would be mitigated by the excavation and disposal alternative. No residual risk would remain.	The soil cover with O&M would prevent industrial worker and ecological receptor exposure to the consolidated soil and sediment contamination causing the unacceptable risks. Implementation and enforcement of LUCs would limit future residential land use (and, hence, residential exposure) and intrusive activities. However, the residual risk would remain unchanged; exposure for industrial workers and ecological receptors would reoccur if the cover integrity is compromised, or potentially occur for residents or other human receptors if the site is developed for nonindustrial use.
Adequacy and Reliability of Controls	Not applicable. No long-term controls implemented.	Not applicable. No long-term controls implemented.	The federal facility has controlled access. LUCs are adequate and reliable when implemented and enforced. The long-term O&M will check and maintain the soil cover (barrier) integrity. Less reliability—and slightly more risk for workers—is anticipated for Alternative 3 than for Alternative 2 because of these long-term post-construction controls and efforts.

TABLE 4-5
SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

NCP Criterion	Alternative 1 No Action	Alternative 2 Excavation and Off-Site Disposal	Alternative 3 Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
Need for Five-Year Review	No, because it is a "no-action" alternative; however, it is recognized that Five-Year Reviews are required under CERCLA if a site has not achieved UU/UE status.	No.	Yes.
Need for Long-Term Management	Not applicable.	No.	Long-term O&M and LUCs must be performed and maintained for protectiveness. LUC and soil cover inspections must be performed periodically. The soil cover integrity (e.g., erosion or animal burrows) must be maintained periodically. If property ownership is transferred with contamination remaining in place, then Environmental Land Use Restrictions (ELURs) would be recorded.

NCP Criterion	Alternative 1 No Action	Alternative 2 Excavation and Off-Site Disposal	Alternative 3 Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT			
Treatment Process Used	No treatment would be employed under the no-action alternative.	While all contaminated media would be disposed of off-site, on-site chemical stabilization treatment of lead in the soil/sediment matrix would be performed to render any hazardous materials to nonhazardous prior to off-site transportation and disposal (if needed; depending on waste characterization results).	On-site chemical stabilization treatment of lead in the soil/sediment matrix would be performed to render any hazardous materials to nonhazardous prior to covering with a soil cover (both excavated soils to be consolidated and in situ soils to be covered) (if needed; depending on waste characterization results). The soil cover would be constructed and maintained on-site.
Amount Destroyed or Treated	No treatment would be employed under the no-action alternative.	Assuming 25% (estimated 2,200 tons) of excavated soil/sediment would be treated on-site to stabilize lead leachability prior to off-site disposal as nonhazardous waste (depending on waste characterization results).	Assuming 25% (estimated 2,200 tons) of in situ or excavated-to-be-consolidated soil/sediment would be treated on-site to stabilize lead leachability prior to covering (depending on waste characterization results). The soil cover would be constructed and maintained on-site.

NCP Criterion	Alternative 1 No Action	Alternative 2 Excavation and Off-Site Disposal	Alternative 3 Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
Reduction of Toxicity, Mobility, or Volume Through Treatment	No treatment would be employed under the no-action alternative.	An assumed 2,200 tons of soil and sediment would be treated on-site to reduce lead leachability (pending waste characterization testing, which mimics more acidic landfill conditions). This will allow for nonhazardous off-site transportation and disposal of all materials.	An assumed 2,200 tons of soil and sediment would be treated on-site to reduce lead leachability (pending waste characterization testing, which mimics more acidic landfill conditions). This will allow for placing/covering nonhazardous in situ and consolidated soils on-site. Also, mobility would be reduced by the consolidation of the contaminated media under the 2-foot soil cover. Also, incidental compaction during consolidation may reduce the overall volume of contaminated media.
SHORT-TERM EFFECTIVENESS			
Community Protection	No additional risk to community because no actions are taken.	Some short-term risk to community is expected due to transportation/hauling of equipment, excavated materials for disposal (8,830 tons), and imported backfill (8,830 tons). Risks would be minimized through engineering controls, traffic control planning and haul routes, and use of experienced firms and personnel. More long-haul traffic is anticipated for Alternative 2 than for Alternative 3 due to the off-site disposal of excavated waste.	Some short-term risk to community is expected due to transportation/hauling of equipment and imported backfill (15,100 tons). Risks would be minimized through engineering controls, traffic control planning and haul routes, and use of experienced firms and personnel. More backfill will be imported to the site for Alternative 3 due to the soil cover construction; however, the backfill transportation distances are shorter than those for Alternative 2’s off-site waste disposal.

TABLE 4-5
SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES
FEASIBILITY STUDY
SKEET RANGE MRS - FUDS PROJECT 9
NASA WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VIRGINIA

NCP Criterion	Alternative 1 No Action	Alternative 2 Excavation and Off-Site Disposal	Alternative 3 Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
Worker Protection	No risk to workers because no actions are taken.	No significant risk to workers is anticipated if proper PPE and typical safe work practices are used during excavation, backfilling, restoration, and transportation and disposal activities.	No significant risk to workers anticipated if proper PPE and typical safe work practices are used during excavation, backfilling, consolidation, soil cover installation, and restoration activities. More risk to site workers could be anticipated for Alternative 3 than for Alternative 2 because of the long-term post-construction controls and efforts (i.e., LUC/soil cover inspections and O&M of the soil cover).
Environmental Impacts	Additional adverse impact to the environment would be expected because no action is taken to address the ecological risks.	Best management practices and other engineering controls would minimize environmental impacts during excavation, backfilling, and restoration activities. Erosion and sediment (E&S) control measures would be used to prevent damage to the environment from soil/sediment runoff.	Best management practices and other engineering controls would minimize environmental impacts during excavation, backfilling, restoration, consolidation, and soil cover construction activities, as well as during establishment of vegetation on the soil cover. E&S control measures would be used to prevent damage to the environment from soil/sediment runoff.

NCP Criterion	Alternative 1 No Action	Alternative 2 Excavation and Off-Site Disposal	Alternative 3 Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
Time until Remedial Action is Complete	Not Applicable.	3 months to complete on-site construction and off-site transportation and disposal. Additional/typical post-construction monitoring of revegetation and subsequently removing the E&S controls. Would attain unrestricted use and unlimited exposure (UU/UE).	3 months to complete on-site construction. Additional/typical post-construction monitoring of revegetation and subsequently removing the E&S controls. Long-term O&M and LUCs in perpetuity; would not attain UU/UE.
IMPLEMENTABILITY			
Ability to Construct and Operate	Not applicable.	Other than coordination with the airfield, no major difficulties are anticipated based on previous remedial actions at the facility. Excavation, backfilling, restoration, and off-site disposal are readily implementable practices. Chemical stabilization of lead is also an established, readily implementable technology.	Other than coordination with the airfield, no major difficulties are anticipated based on previous remedial actions at the facility. Excavation, consolidation, backfilling, restoration, and construction of a soil cover are readily implementable technologies. However, the future mission of the NOAA antennae facility and the NASA airfield (e.g., expansions) could be impacted by the 2-acre covered soil area to be established in proximity to them.
Reliability of the Technology	Not applicable.	Reliable.	Reliable. Future controls and actions are reliable albeit in perpetuity.

NCP Criterion	Alternative 1 No Action	Alternative 2 Excavation and Off-Site Disposal	Alternative 3 Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
Ease of Doing More Action if Needed	Additional actions would be easily implemented if required.	Additional actions would be easily implemented if required (e.g., expand excavation areas).	Additional actions would be easily implemented if required (e.g., expand excavation areas or change consolidation/cover area configuration).
Ability to Monitor Effectiveness	No monitoring would occur under the no-action alternative.	Not applicable other than confirmation sampling prior to completion.	Confirmation sampling would occur prior to completion of construction. Long-term O&M and inspections would be required to confirm and maintain cover integrity and LUCs; assuming major soil cover maintenance every 5 years. Future monitoring is straight-forward albeit in perpetuity.

NCP Criterion	Alternative 1 No Action	Alternative 2 Excavation and Off-Site Disposal	Alternative 3 Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
Ability to Obtain Approvals and Coordinate with Other Agencies	Not applicable.	Would comply with all ARARs. Coordination with federal and state agencies, along with appropriate Native American tribes, would be required for working near the coast, near endangered or threatened species, wetlands, and/or cultural resources, as well as for disturbing/constructing a sizable area (4.4 acres under Alternative 2); however, no permits would be required because the CERCLA remedial action would occur on-site. These processes have been performed for other remedial actions at the facility. Typical coordination for transportation and off-site disposal of excavated materials. On-site treatment to chemically stabilize lead in soils (if needed) could be performed under USEPA's AOC Policy (see Table 4-4).	Would comply with all ARARs. Coordination with federal, state, and base agencies, and Native American tribes would be required working near the coast, near endangered or threatened species, wetlands, and cultural resources, as well as for disturbing/constructing a sizable area (4.5 acres under Alternative 3); however, no permits would be required because the CERCLA remedial action would occur on-site. These processes have been performed for other remedial actions at the facility. On-site treatment to chemically stabilize lead in soils (if needed) could be performed under USEPA's AOC Policy (see Table 4-4). LUCs should not be difficult to implement and enforce. Would require periodic coordination with airfield and potentially NOAA antenna facility for inspections and O&M.
Availability of Treatment, Storage Capacities, and Disposal Services	Not applicable.	Readily available.	Readily available.

NCP Criterion	Alternative 1 No Action	Alternative 2 Excavation and Off-Site Disposal	Alternative 3 Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
Availability of Equipment, Specialists, and Materials	Not applicable.	Ample availability of equipment and personnel to perform excavation, backfilling, and off-site transportation and disposal. Chemical stabilization reagent mixing for lead would require coordination with a specialized subcontractor/vendor.	Ample availability of equipment and personnel to perform excavation and consolidation, backfilling, and construction of the soil cover. Chemical stabilization reagent mixing for lead would require coordination with a specialized subcontractor/vendor. Materials and skills also are available for long-term O&M and LUC implementation and enforcement.
Availability of Technology	Not applicable.	Available. Excavation, chemical stabilization, and off-site disposal are commonly used technologies.	Available. Excavation, consolidation, and soil covers are commonly used technologies.
COST			
Capital Cost	$0	$2,386,000	$1,568,000
O&M Cost	$0	$0	O&M (PV $171K over 100 years) ▪ $500 – Annually ▪ $8K – Every 5 years

NCP Criterion	Alternative 1 No Action	Alternative 2 Excavation and Off-Site Disposal	Alternative 3 Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
Other Periodic Costs (Years 1 to 30)	$0	$0	LUC Inspections/Reporting (PV $231K over 100 years) ▪ $11K – Quarterly Years 1 and 2 ▪ $2K – Annually thereafter 5-Year Reviews (PV $245K over 100 years) ▪ –$15K – Every 5 years
Total Present Value (PV)[1]	$0	$2,386,000	2,216,000 (over 100 years)

Notes:
NCP – National Contingency Plan
RAO – Remedial Action Objective
PPE – Personal protective equipment
USEPA – United States Environmental Protection Agency
O&M – Operation and maintenance
COC – Chemical of Concern
NOAA – National Oceanic and Atmospheric Administration
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
LUC – Land use control
PRG – Preliminary Remediation Goal

1. Present Value (PV) is the present worth cost for Alternative 3 based on an annual real discount rate of 0.4 percent over 100 years in this case (OMB, 2019). For comparison, if estimated over only 30 years, the PV total would be $1,801,000. Estimating over 100 years provides more accurate information to stakeholders per USEPA (2000). See the cost estimates and PV calculations in Appendix C. See a discussion of discounted versus non-discounted future costs in Section 4.3.7.

FIGURES

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Aerial photograph from ESRI Bing Maps map service
(© 2011 Microsoft Corporation and its data suppliers).

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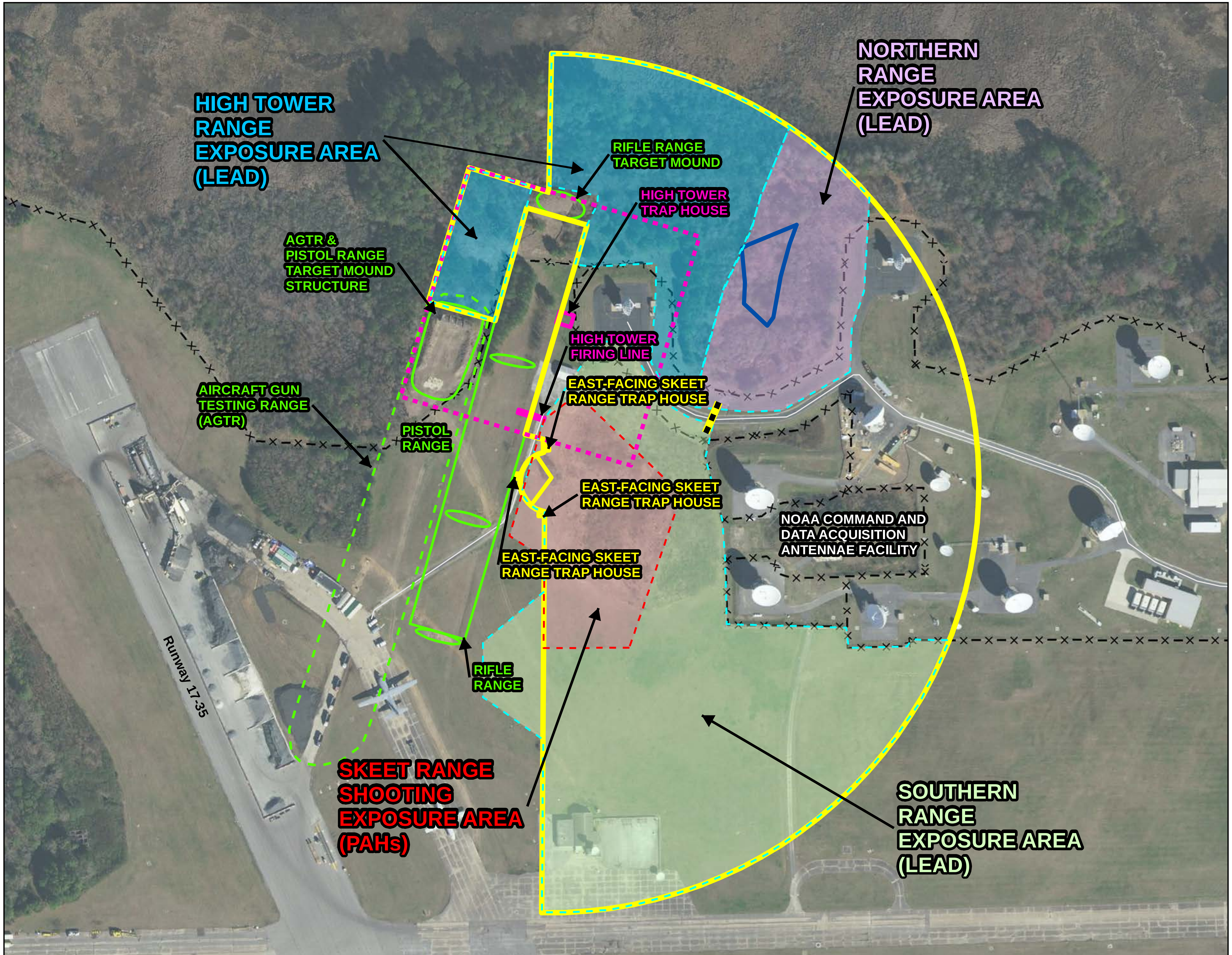
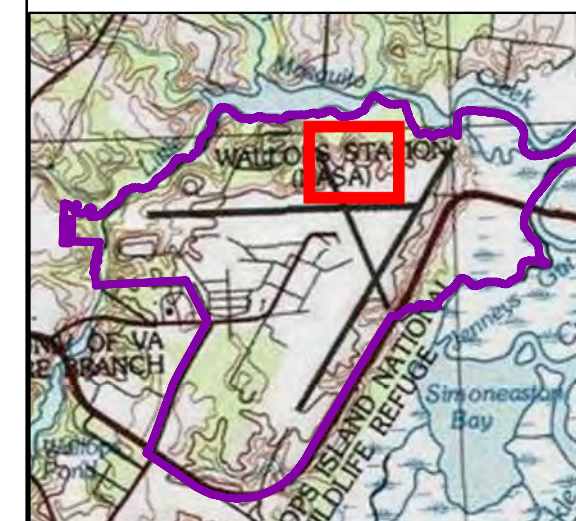
FACILITY AND
SITE LOCATION MAP
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE 112G07696	SCALE AS NOTED
FIGURE NO. 1-1	REV DATE 8/16/16



Legend

- Fenceline
- Lead Exposure Area
- PAH Exposure Area
- Palustrine Forested Wetland (2018)
- High Tower Range
- Approximate AGTR Boundary
- Other MBFR Features
- High Tower Range Exposure Area
- Northern Range Exposure Area
- Skeet Range Shooting Exposure Area (PAHs)
- Southern Range Exposure Area
- Skeet Range MRS
- Installation Boundary
- Culvert



N

0 100 200 400 Feet

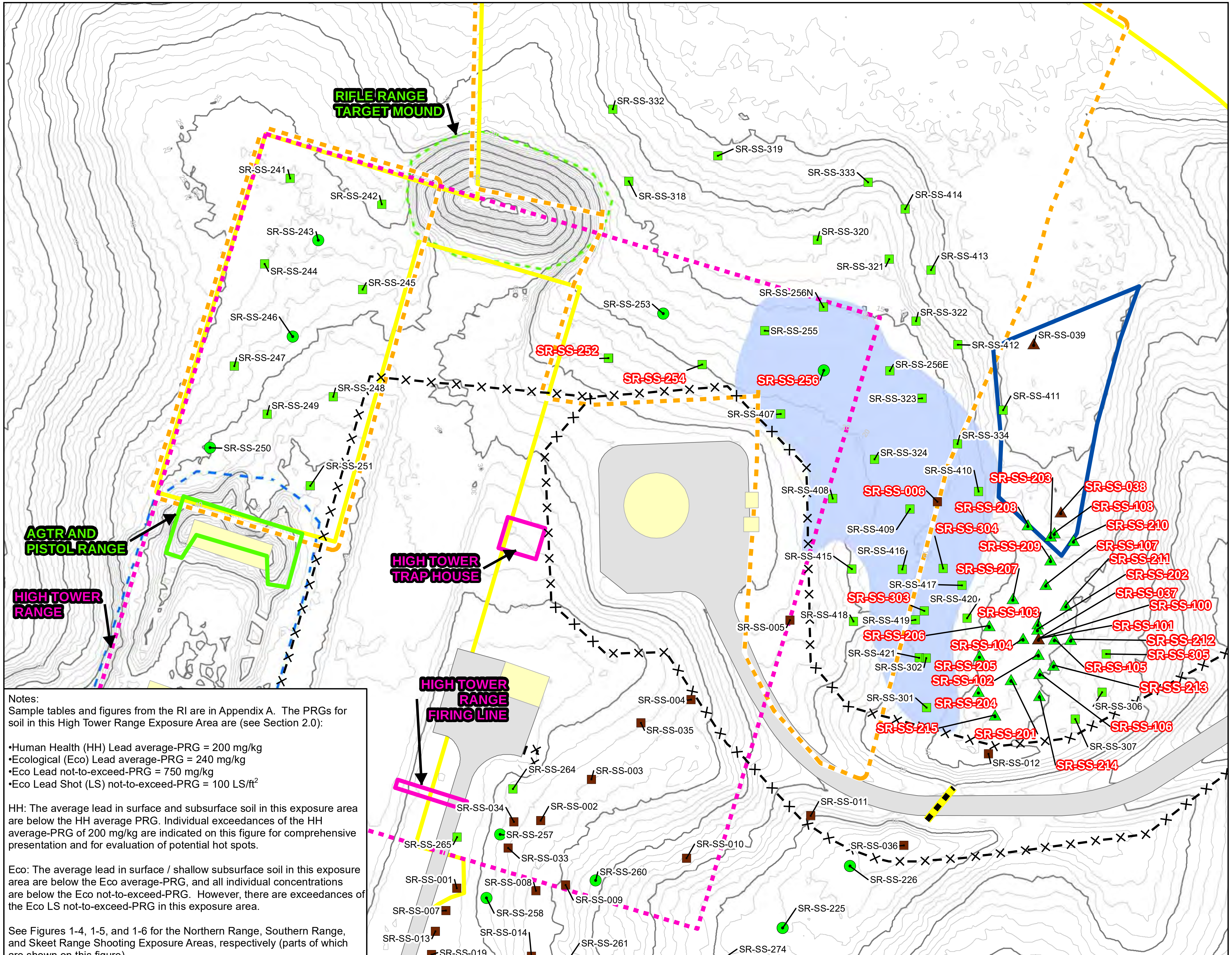
FIGURE 1-2
SITE LAYOUT AND EXPOSURE AREAS
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

11/9/2020

Aerial Imagery 2013 ESRI map service
USA Topo Map 2013 ESRI map service

Coordinate System: North American Datum, 1983 VA South, Meters

NOR: G:\GIS_files\NASA WI\MXD\MBFR\SkeetRange\MBFR_exposure110920.mxd MMC



Notes:
Sample tables and figures from the RI are in Appendix A. The PRGs for soil in this High Tower Range Exposure Area are (see Section 2.0):

- Human Health (HH) Lead average-PRG = 200 mg/kg
- Ecological (Eco) Lead average-PRG = 240 mg/kg
- Eco Lead not-to-exceed-PRG = 750 mg/kg
- Eco Lead Shot (LS) not-to-exceed-PRG = 100 LS/ft^2

HH: The average lead in surface and subsurface soil in this exposure area are below the HH average PRG. Individual exceedances of the HH average-PRG of 200 mg/kg are indicated on this figure for comprehensive presentation and for evaluation of potential hot spots.

Eco: The average lead in surface / shallow subsurface soil in this exposure area are below the Eco average-PRG, and all individual concentrations are below the Eco not-to-exceed-PRG. However, there are exceedances of the Eco LS not-to-exceed-PRG in this exposure area.

See Figures 1-4, 1-5, and 1-6 for the Northern Range, Southern Range, and Skeet Range Shooting Exposure Areas, respectively (parts of which are shown on this figure).

Legend

- SI Sediment Sample
- SI Surface Soil Sample
- RI Sediment Samples
- RI Surface and Subsurface Soil Sample
- RI Surface Soil Sample
- Palustrine Forested Wetland (2018)
- Culvert
- Fence Line
- 2010 LIDAR Contours (feet msl)
- Exceeds 100 LS/Square Foot
- High Tower Range Exposure Area
- Structure Existing Area
- Rifle Range Target Mound
- Approximate AGTR Boundary
- High Tower Range
- Skeet Range MRS
- Paved Surfaces
- SR-SS-038 Lead greater than 200 mg/kg

N

0 30 60 120 Feet

FIGURE 1-3
SAMPLE LOCATIONS AND EXCEEDANCES
HIGH TOWER RANGE EXPOSURE AREA
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

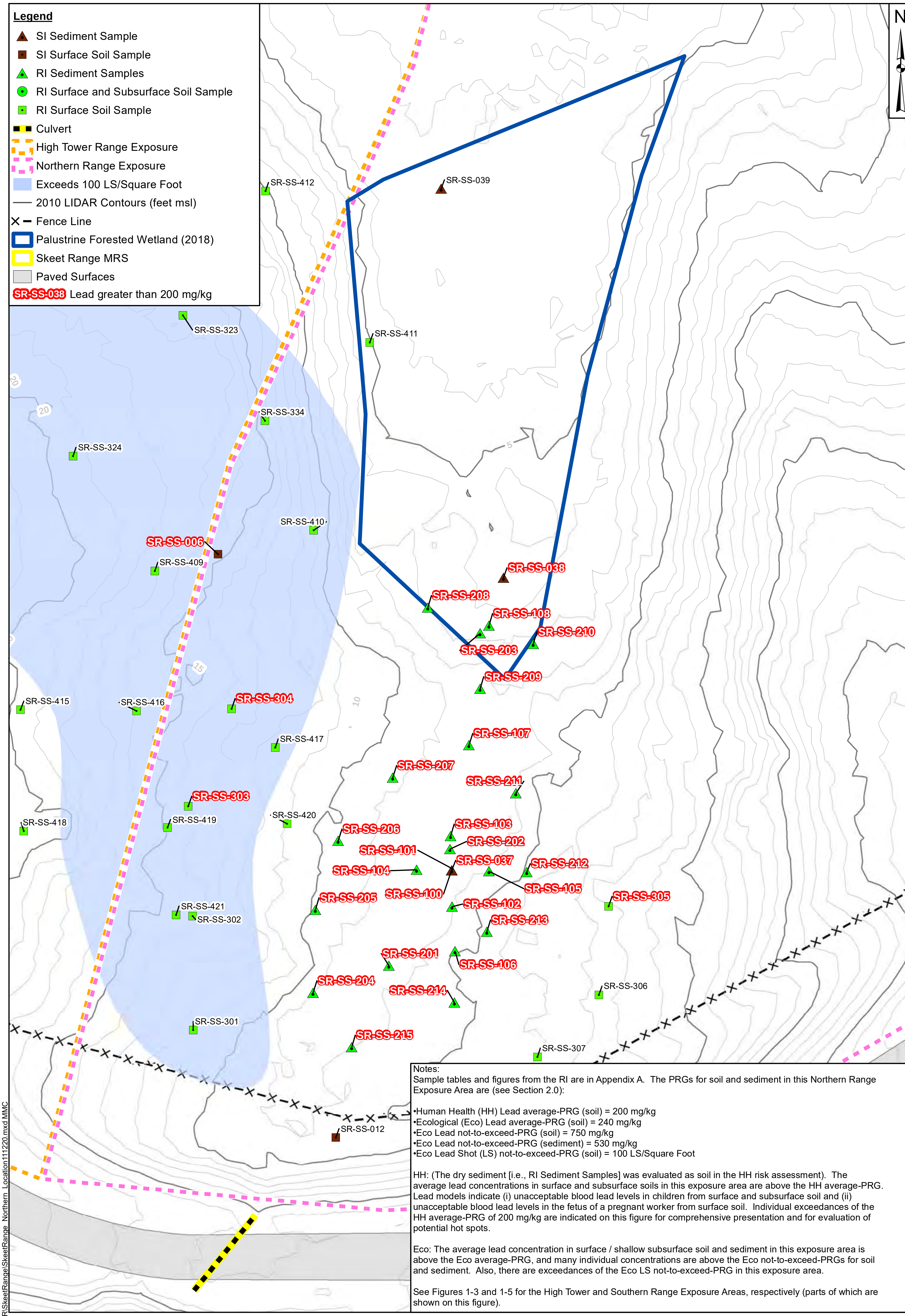
NASA

11/12/2020

Aerial Imagery 2013 ESRI map service

Coordinate System: North American Datum, 1983 VA South, Meters

NOR: G:\GIS_files\NASA WI\MXD\MBFR\SkeetRange\SR_pro_hightower_LSLocation111220.mxd MMC



Notes:
Sample tables and figures from the RI are in Appendix A. The PRGs for soil and sediment in this Northern Range Exposure Area are (see Section 2.0):

- Human Health (HH) Lead average-PRG (soil) = 200 mg/kg
- Ecological (Eco) Lead average-PRG (soil) = 240 mg/kg
- Eco Lead not-to-exceed-PRG (soil) = 750 mg/kg
- Eco Lead not-to-exceed-PRG (sediment) = 530 mg/kg
- Eco Lead Shot (LS) not-to-exceed-PRG (soil) = 100 LS/Square Foot

HH: (The dry sediment [i.e., RI Sediment Samples] was evaluated as soil in the HH risk assessment). The average lead concentrations in surface and subsurface soils in this exposure area are above the HH average-PRG. Lead models indicate (i) unacceptable blood lead levels in children from surface and subsurface soil and (ii) unacceptable blood lead levels in the fetus of a pregnant worker from surface soil. Individual exceedances of the HH average-PRG of 200 mg/kg are indicated on this figure for comprehensive presentation and for evaluation of potential hot spots.

Eco: The average lead concentration in surface / shallow subsurface soil and sediment in this exposure area is above the Eco average-PRG, and many individual concentrations are above the Eco not-to-exceed-PRGs for soil and sediment. Also, there are exceedances of the Eco LS not-to-exceed-PRG in this exposure area.

See Figures 1-3 and 1-5 for the High Tower and Southern Range Exposure Areas, respectively (parts of which are shown on this figure).

Base Map:
Aerial Imagery 2013 ESRI map service

SAMPLE LOCATIONS AND EXCEEDANCES
NORTHERN RANGE EXPOSURE AREA
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

Feet: 0 — 30 — 60

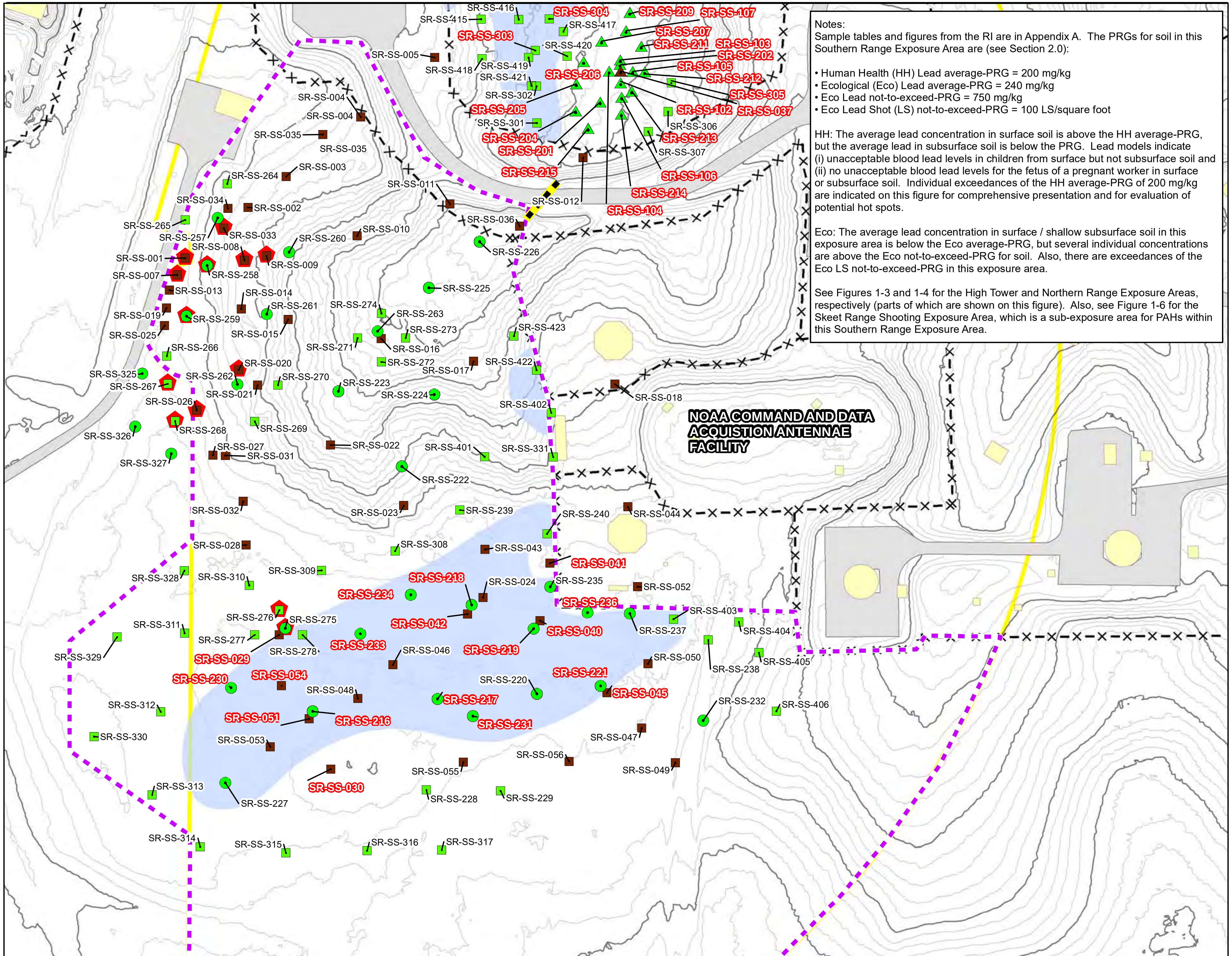
FIGURE: 1-4

Prepared For: NASA

Prepared By: TETRA TECH

Date: 11/12/2020

NOR: G:\GIS_files\NASA WI\MXD\MBFR\SkeetRange\SkeetRange_Northern_Location111220.mxd MMC



Notes:
Sample tables and figures from the RI are in Appendix A. The PRGs for soil in this Southern Range Exposure Area are (see Section 2.0):

- Human Health (HH) Lead average-PRG = 200 mg/kg
- Ecological (Eco) Lead average-PRG = 240 mg/kg
- Eco Lead not-to-exceed-PRG = 750 mg/kg
- Eco Lead Shot (LS) not-to-exceed-PRG = 100 LS/square foot

HH: The average lead concentration in surface soil is above the HH average-PRG, but the average lead in subsurface soil is below the PRG. Lead models indicate (i) unacceptable blood lead levels in children from surface but not subsurface soil and (ii) no unacceptable blood lead levels for the fetus of a pregnant worker in surface or subsurface soil. Individual exceedances of the HH average-PRG of 200 mg/kg are indicated on this figure for comprehensive presentation and for evaluation of potential hot spots.

Eco: The average lead concentration in surface / shallow subsurface soil in this exposure area is below the Eco average-PRG, but several individual concentrations are above the Eco not-to-exceed-PRG for soil. Also, there are exceedances of the Eco LS not-to-exceed-PRG in this exposure area.

See Figures 1-3 and 1-4 for the High Tower and Northern Range Exposure Areas, respectively (parts of which are shown on this figure). Also, see Figure 1-6 for the Skeet Range Shooting Exposure Area, which is a sub-exposure area for PAHs within this Southern Range Exposure Area.

Legend

- Si Sediment Sample
- SI Surface Soil Sample
- RI Sediment Samples
- RI Surface and Subsurface Soil Sample
- RI Surface Soil Sample
- Total risk from PAH COCs > 1 x 10^{-4}
- Exceeds 100 LS/Square Foot
- Culvert
- 2010 LIDAR Contours (feet msl)
- Fence Line
- Southern Range Exposure Area
- Structure Existing Area
- Skeet Range MRS
- Paved Surfaces
- SR-SS-038 Lead greater than 200 mg/kg

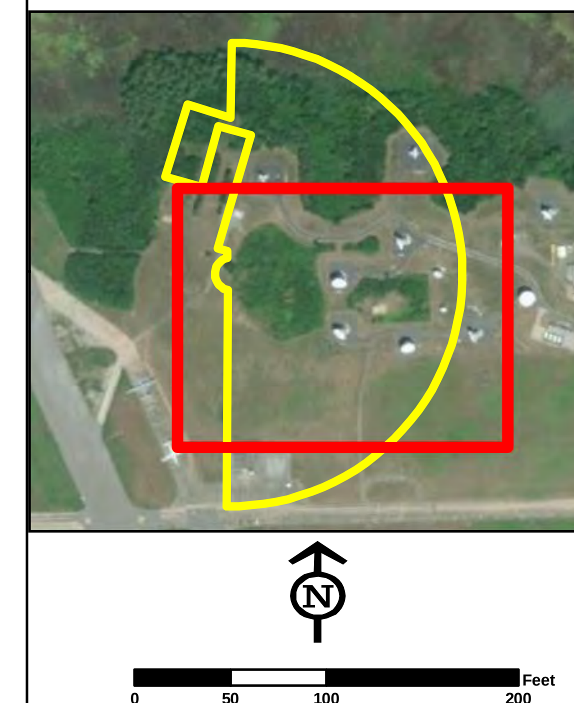


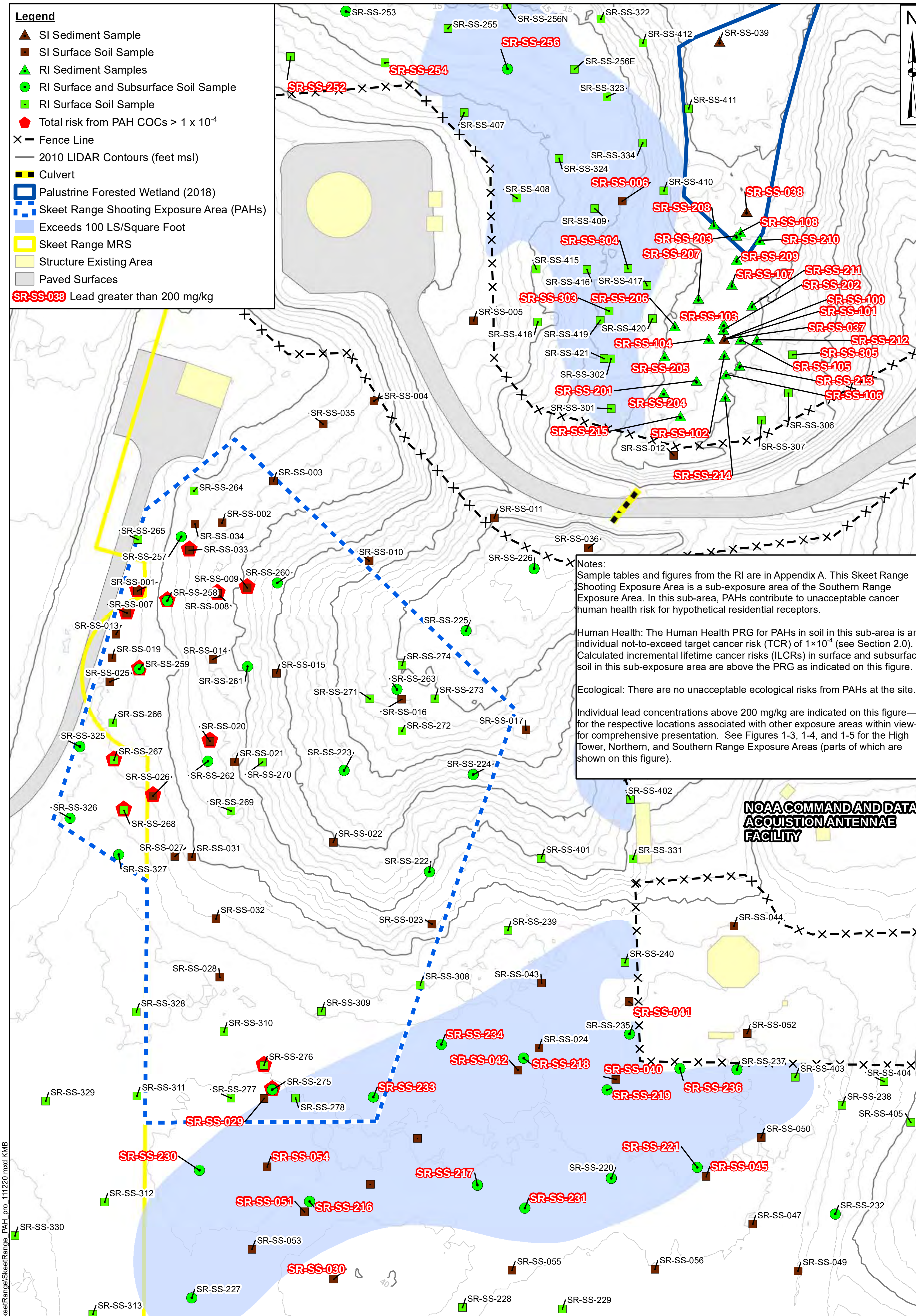
FIGURE 1-5
SAMPLE LOCATIONS AND EXCEEDANCES
SOUTHERN RANGE EXPOSURE AREA
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

3/17/2021

Aerial Imagery 2013 ESRI map service

Coordinate System: North American Datum, 1983 VA South, Meters

NOR: G:\GIS_files\NASA WI\MXD\MBFR\SkeetRange\SR_southern_LSLocation_111220.mxd MMC

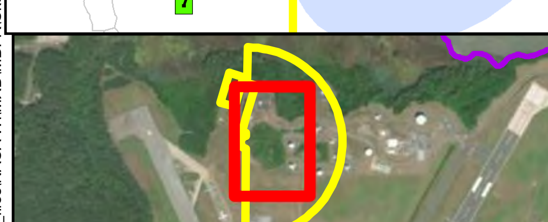


Notes:
Sample tables and figures from the RI are in Appendix A. This Skeet Range Shooting Exposure Area is a sub-exposure area of the Southern Range Exposure Area. In this sub-area, PAHs contribute to unacceptable cancer human health risk for hypothetical residential receptors.

Human Health: The Human Health PRG for PAHs in soil in this sub-area is an individual not-to-exceed target cancer risk (TCR) of 1×10^{-4} (see Section 2.0). Calculated incremental lifetime cancer risks (ILCRs) in surface and subsurface soil in this sub-exposure area are above the PRG as indicated on this figure.

Ecological: There are no unacceptable ecological risks from PAHs at the site.

Individual lead concentrations above 200 mg/kg are indicated on this figure—for the respective locations associated with other exposure areas within view—for comprehensive presentation. See Figures 1-3, 1-4, and 1-5 for the High Tower, Northern, and Southern Range Exposure Areas (parts of which are shown on this figure).



Base Map:
Aerial Imagery 2013 ESRI map service

SAMPLE LOCATIONS AND EXCEEDANCES
SKEET RANGE SHOOTING EXPOSURE AREA
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

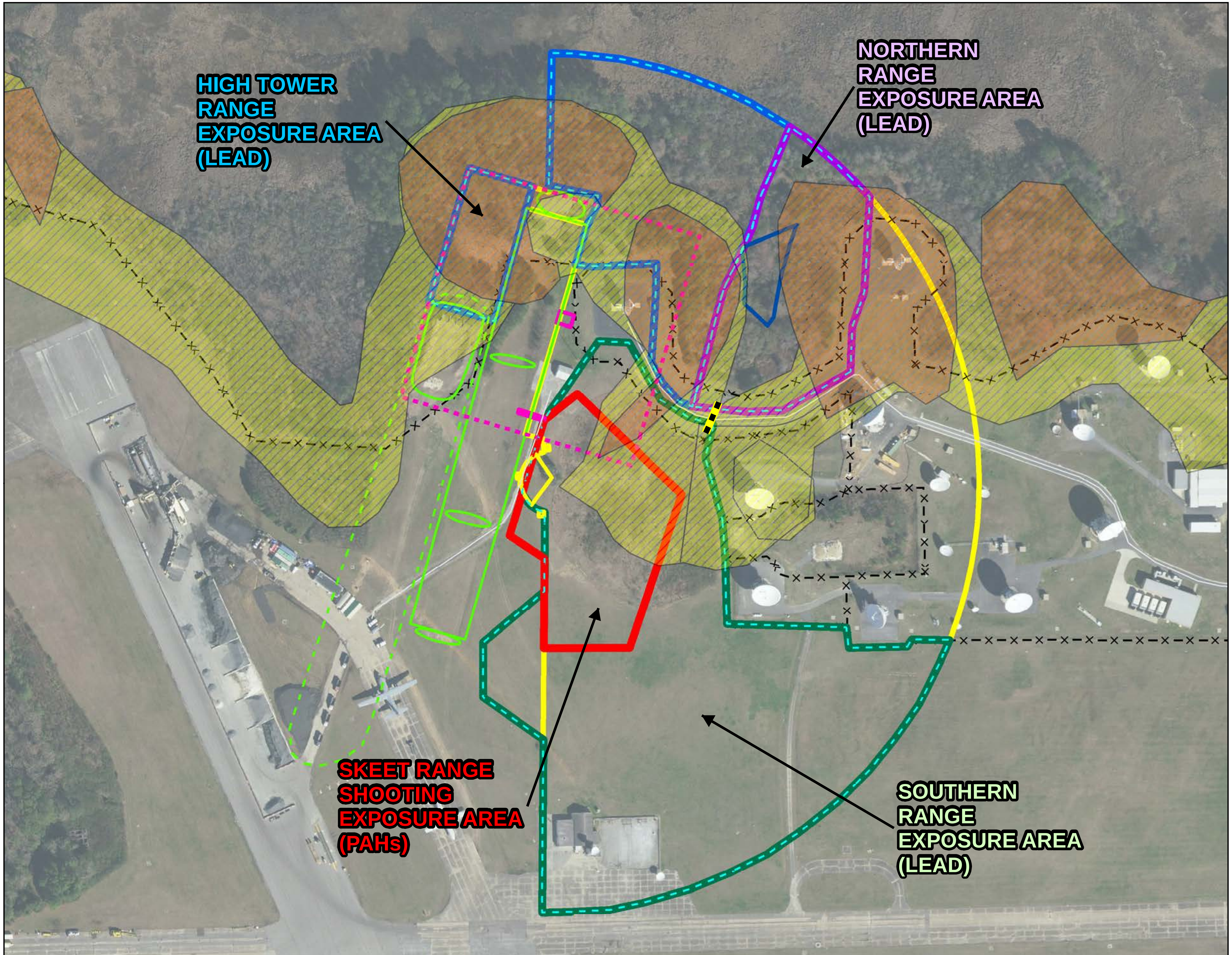
Feet
0 70 140

FIGURE: 1-6

Prepared For: NASA

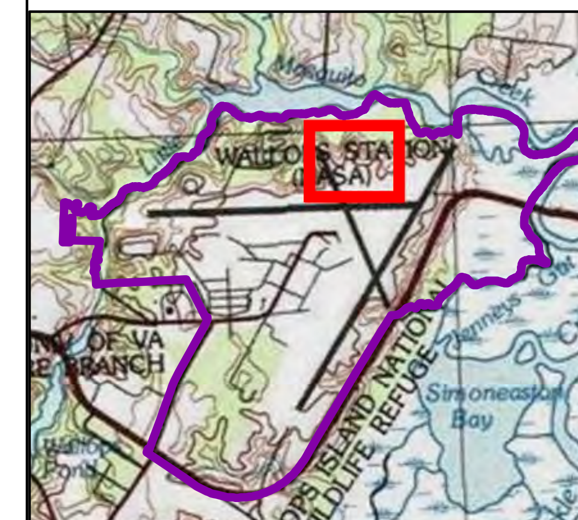
Prepared By:

Date: 3/17/2021



Legend

- High Cultural Sensitivity
- Medium Cultural Sensitivity
- Fenceline
- Lead Exposure Area
- PAH Exposure Area
- Palustrine Forested Wetland
- Other MBFR Features
- High Tower Range
- Approximate AGTR Boundary
- Lead Exposure Area
- PAH Exposure Area
- High Tower Range Exposure Area
- Northern Range Exposure Area
- Skeet Range Shooting Exposure Area (PAHs)
- Southern Range Exposure Area
- Skeet Range MRS
- Installation Boundary
- Culvert



N

0 100 200 400 Feet

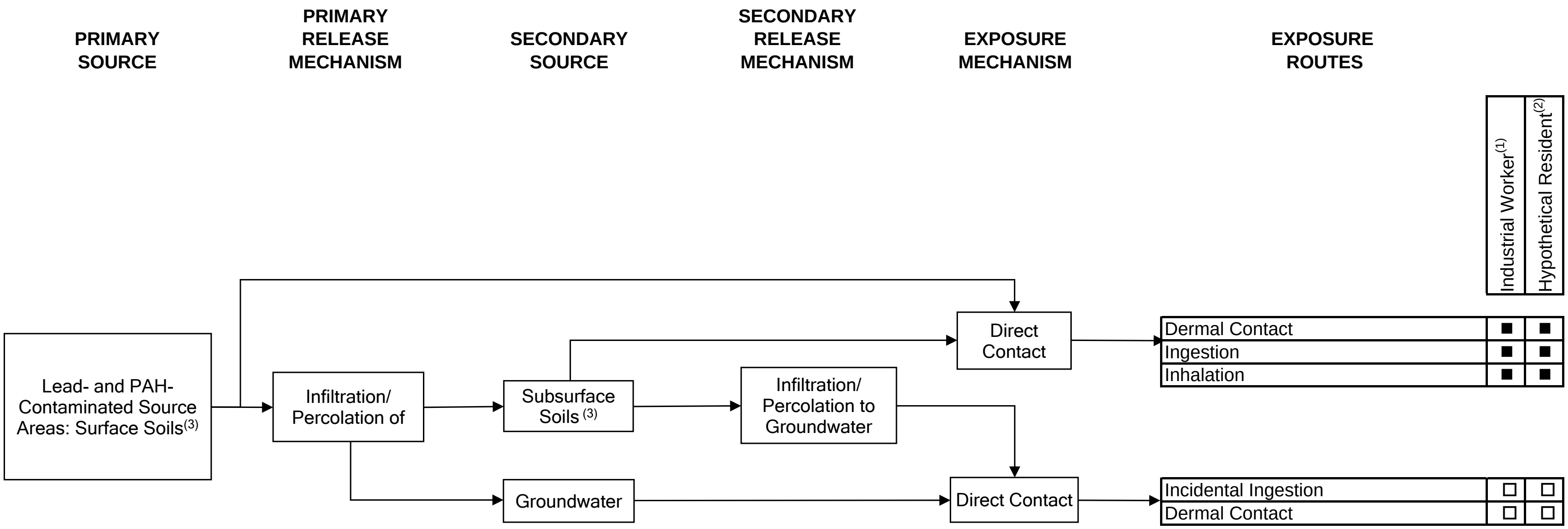
FIGURE 1-7
CULTURAL SENSITIVE AREAS
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

TETRA TECH | 8/26/2021

Aerial Imagery 2013 ESRI map service
USA Topo Map 2013 ESRI map service

Coordinate System: North American Datum, 1983 VA South, Meters

NOR: G:\GIS_files\NASA WI\MXD\MBFR\SkeetRange\MBFR_exposure062320.mxd SKS

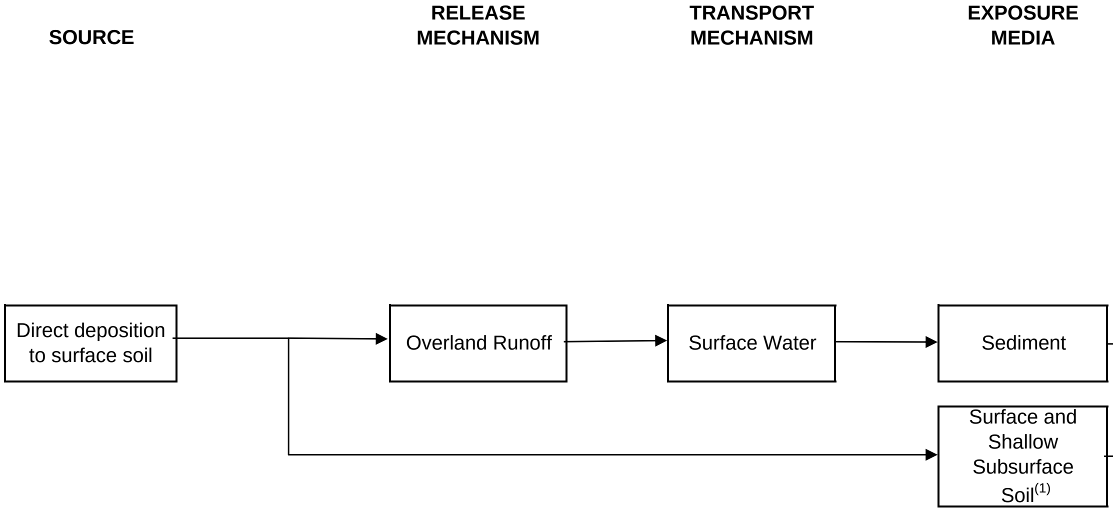


LEGEND

- ■ Exposure pathway that is quantitatively evaluated in the Human Health Risk Assessment.
- □ Represents an incomplete exposure pathway based on available contaminant concentration data.

1. Potential receptor under current or future land use
2. Potential (but unlikely) receptor under future land use. Evaluated for decision-making purposes.
3. In the Human Health Risk Evaluation, surface soil is defined as 0-6 inches and subsurface soil as 6-24 inches below ground surface.

FIGURE 1-8
HUMAN HEALTH EXPOSURE PATHWAY ANALYSIS
FEASIBILITY STUDY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY, VIRGINIA



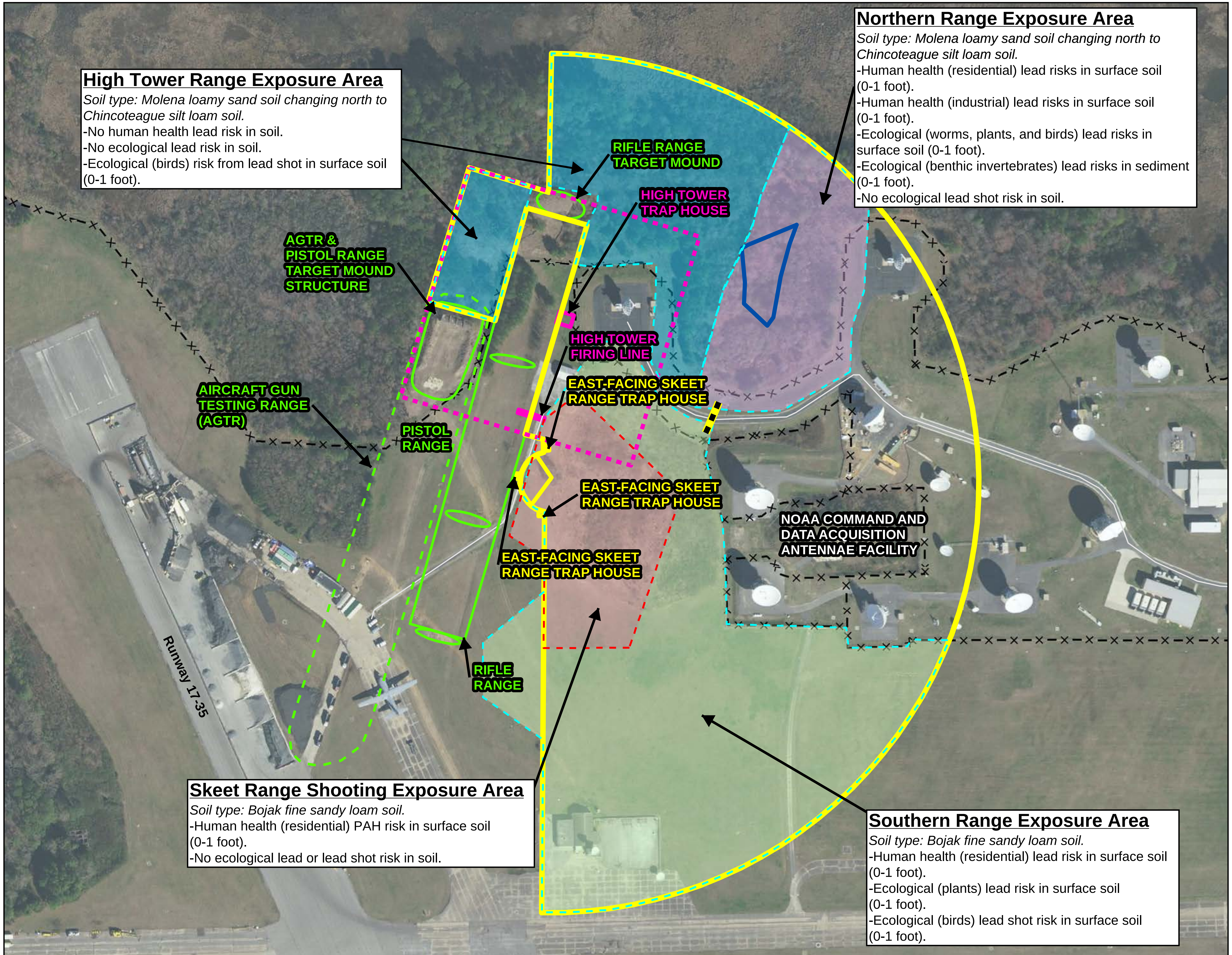
EXPOSURE ROUTE

Exposure Media	Exposure Route	Terrestrial Vegetation	Soil Invertebrates	Sediment Invertebrates	Birds	Mammals
Sediment	Direct contact			■		
Sediment	Ingestion of sediment			■		
Sediment	Ingestion of food			■	□	□
Surface and Shallow Subsurface Soil[1]	Direct Contact	■	■		□	□
Surface and Shallow Subsurface Soil[1]	Ingestion of soil		■		■	■
Surface and Shallow Subsurface Soil[1]	Ingestion of food		■		■	■
Surface and Shallow Subsurface Soil[1]	Ingestion of lead shot				■	

Legend
■ = Complete Exposure Pathway
□ = Complete Exposure Pathway, but not evaluated because it is considered to be insignificant.

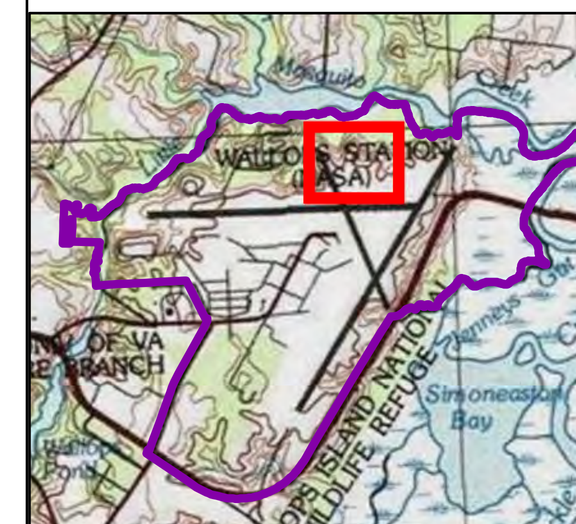
Blank space indicates incomplete exposure pathway or relatively insignificant, or not applicable, potential exposure.
1. In the screening-level Ecological Risk Assessment, surface soil is defined as 0-6 inches, shallow subsurface soil as 6-12 inches, and subsurface soil is 12-24 inches below ground surface.

FIGURE 1-9
ECOLOGICAL EXPOSURE PATHWAY ANALYSIS
FEASIBILITY STUDY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY, VIRGINIA



Legend

- Fenceline
- Lead Exposure Area
- PAH Exposure Area
- Palustrine Forested Wetland (2018)
- High Tower Range
- Approximate AGTR Boundary
- Other MBFR Features
- High Tower Range Exposure Area
- Northern Range Exposure Area
- Skeet Range Shooting Exposure Area (PAHs)
- Southern Range Exposure Area
- Skeet Range MRS
- Culvert



N

0 100 200 400 Feet

FIGURE 2-1
RISKS IN EXPOSURE AREAS
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

12/07/2020

Aerial Imagery 2013 ESRI map service
USA Topo Map 2013 ESRI map service

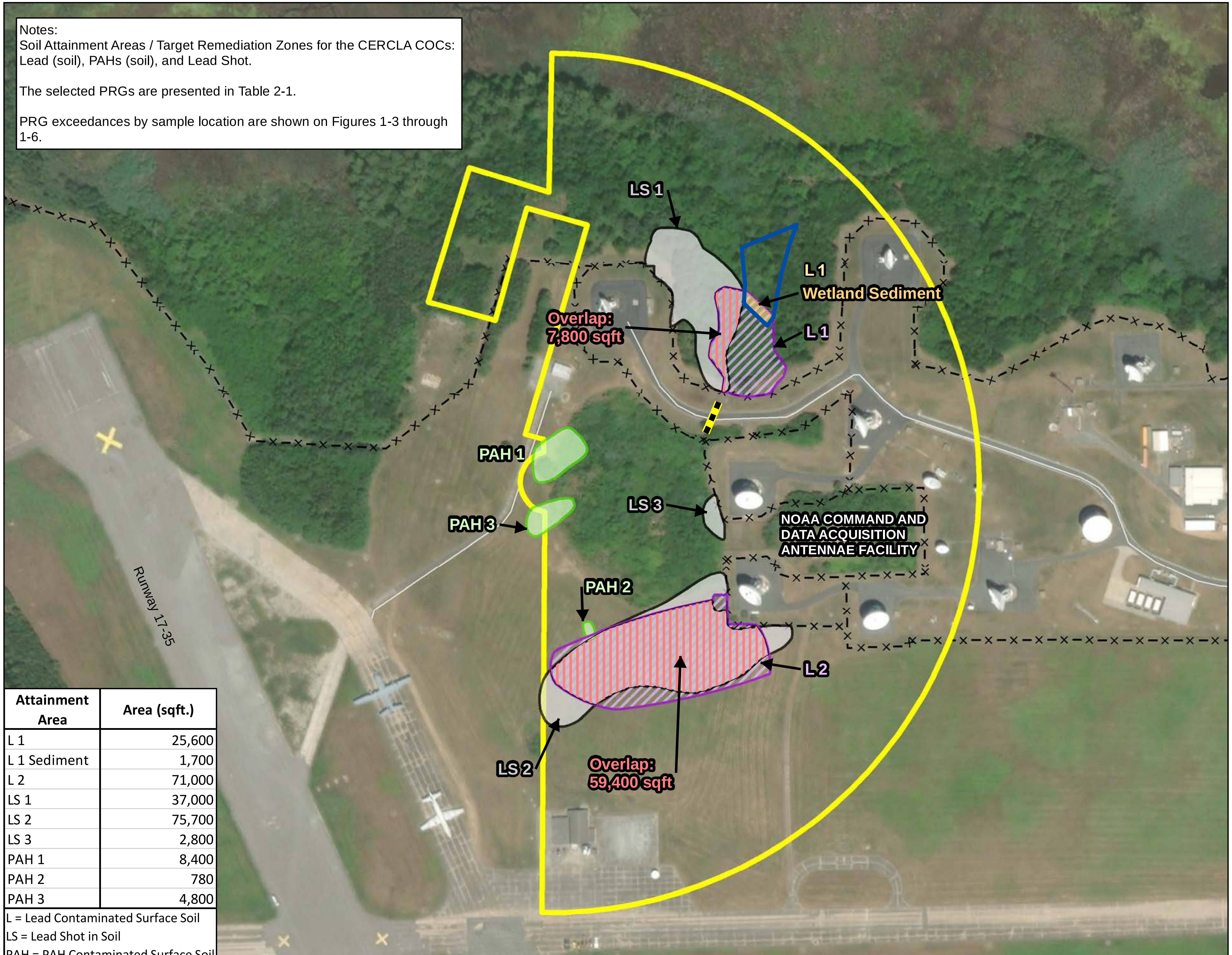
Coordinate System: North American Datum, 1983 VA South, Meters

NOR: G:\GIS_files\NASA WI\MXD\MBFR\SkeetRange\MBFR_exposure110920.mxd MMC

Notes:
Soil Attainment Areas / Target Remediation Zones for the CERCLA COCs: Lead (soil), PAHs (soil), and Lead Shot.

The selected PRGs are presented in Table 2-1.

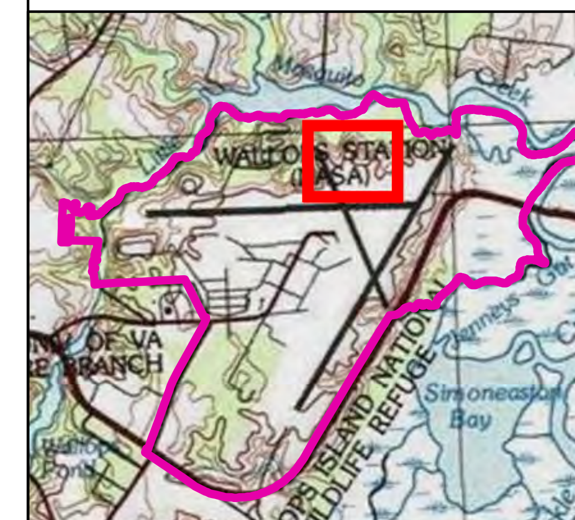
PRG exceedances by sample location are shown on Figures 1-3 through 1-6.



Attainment Area	Area (sqft.)
L 1	25,600
L 1 Sediment	1,700
L 2	71,000
LS 1	37,000
LS 2	75,700
LS 3	2,800
PAH 1	8,400
PAH 2	780
PAH 3	4,800

L = Lead Contaminated Surface Soil
LS = Lead Shot in Soil
PAH = PAH Contaminated Surface Soil

Legend
- Palustrine Forested Wetland (2018)
- Fenceline
- Exceeds 100 Lead Shot/Square Foot
- PAH Risk >1x10^{-4}
- Average Lead in Soil>200 mg/kg (0-6" and 6-12")
- Lead in Soil and Lead Shot Overlap
- Delineated Wetland Sediment (2018)
- Skeet Range MRS
- Culvert



N

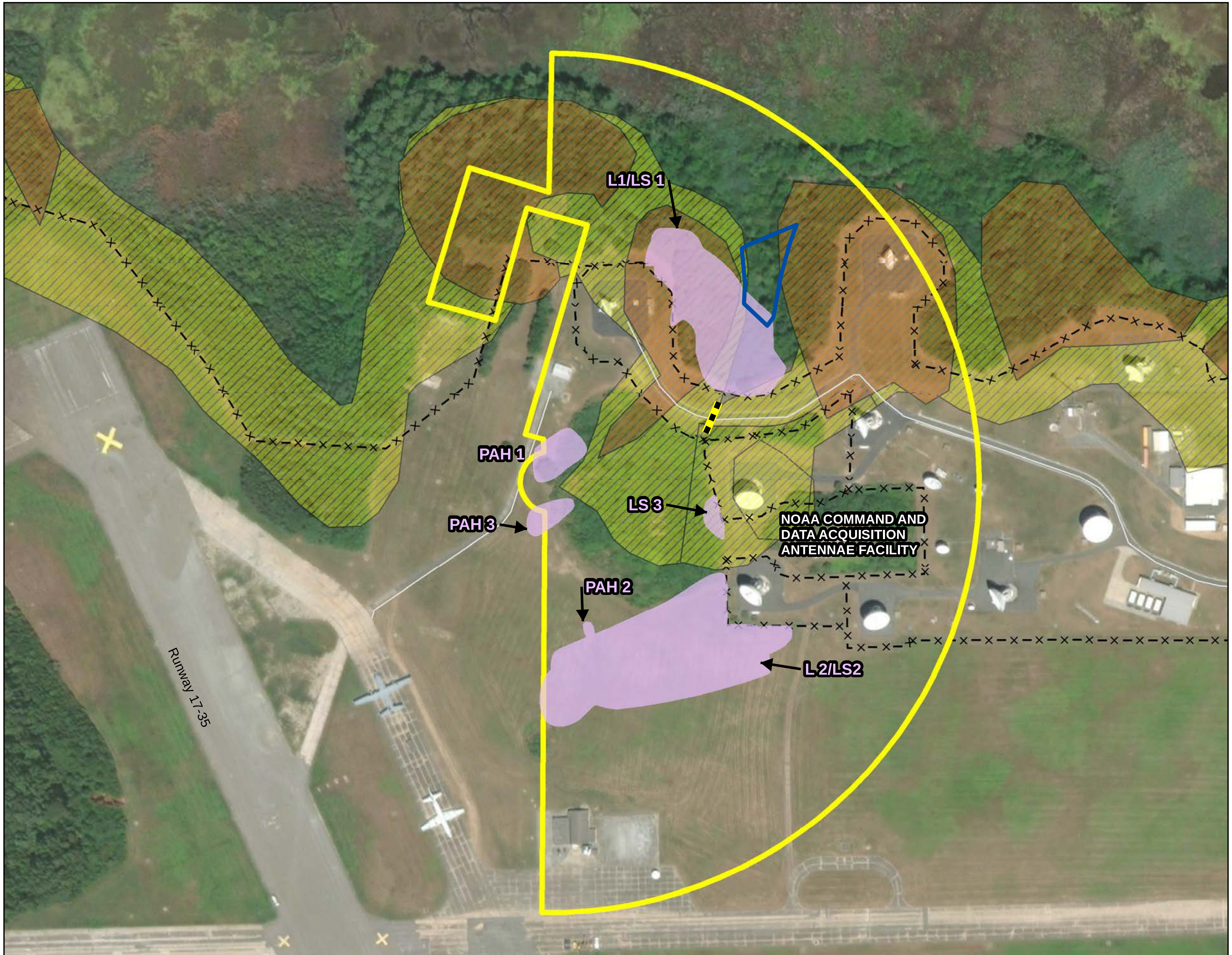
0 100 200 400 Feet

FIGURE 2-2
SOIL ATTAINMENT AREAS
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

3/17/2021

Aerial Imagery 2013 ESRI map service
USA Topo Map 2013 ESRI map service

Coordinate System: North American Datum, 1983 VA South, Meters

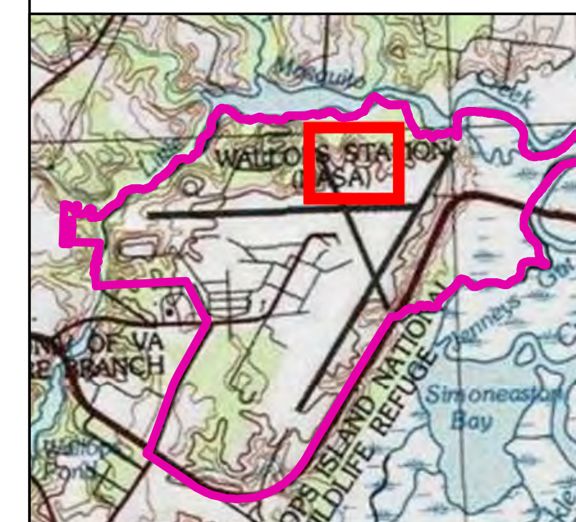


Legend

- High Cultural Sensitivity
- Medium Cultural Sensitivity
- Palustrine Forested Wetland (2018)
- Fenceline
- Areas for Excavation (0-1 Foot)
- Skeet Range MRS
- Culvert

Notes:

- All excavations will be conducted to 1 foot below ground surface. This depth would address all risk.
- All excavated PAH contaminated soil would be classified as non-hazardous.
- Approximately 70% of excavated lead- and lead shot- contaminated soil would be characterized as hazardous waste. The remaining 30% would be classified as non-hazardous waste.
- Hazardous and non-hazardous wastes would be transported off site to their respective appropriate disposal facilities.
- Excavated areas would be backfilled and restored to origninal physical site conditions to the extent practical.



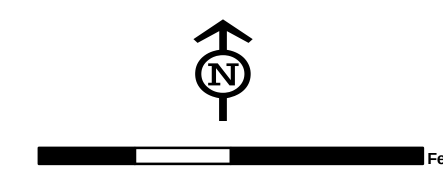
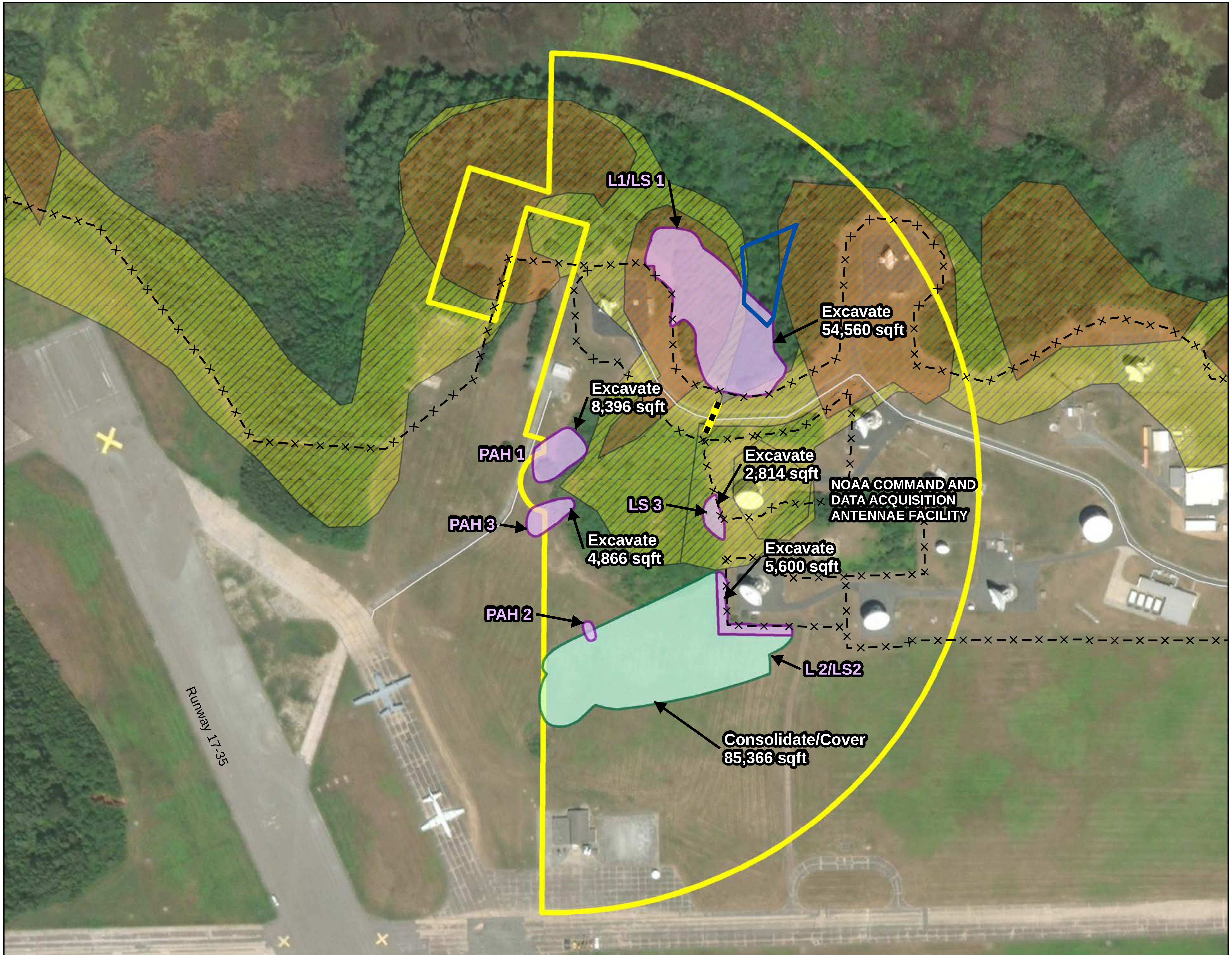


FIGURE 4-1
ALTERNATIVE 2- EXCAVATION AND OFF-SITE DISPOSAL
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

8/26/2021

Aerial Imagery 2013 ESRI map service
USA Topo Map 2013 ESRI map service
Coordinate System: North American Datum, 1983 VA South, Meters

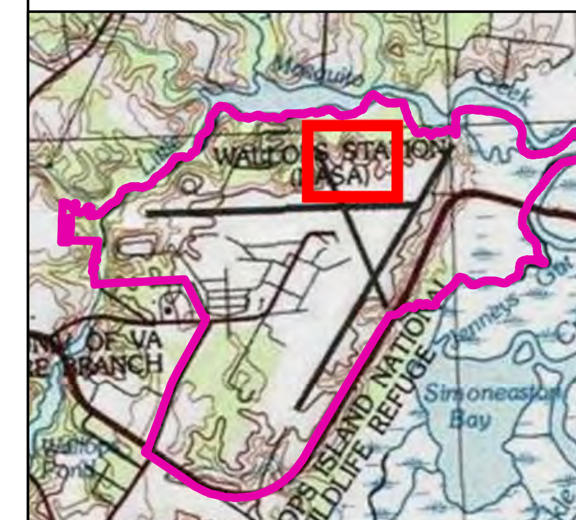
NOR: G:\GIS_files\NASA WI\MXD\MBFR\SkeetRange\MBFR_Excavation1_031721.mxd SKS



Legend

- High Cultural Sensitivity
- Medium Cultural Sensitivity
- Fenceline
- Palustrine Forested Wetland (2018)
- Consolidate/ Cover Area
- Excavation Area
- Skeet Range MRS
- Culvert

Notes:
- All excavations will be conducted to 1 foot below ground surface. This depth would address all risk.
- Excavated areas would be backfilled and restored to original physical site conditions to the extent practical.
- Consolidated soil will be spread in the area with 1 foot thickness and covered with approximately 2 feet of topsoil and vegetation.
- The soil cover will be subject to Land Use Controls and continued O&M.



N

0 100 200 400 Feet

FIGURE 4-2
ALTERNATIVE 3- EXCAVATION,
ON-SITE CONSOLIDATION UNDER COVER,
AND LUCs
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

8/26/2021

Aerial Imagery 2013 ESRI map service
USA Topo Map 2013 ESRI map service

Coordinate System: North American Datum, 1983 VA South, Meters

NOR: G:\GIS_files\NASA WI\MXD\MBFR\SkeetRange\MBFR_Excavation3_031721_V2.mxd SKS

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Appendix A
Historical Information

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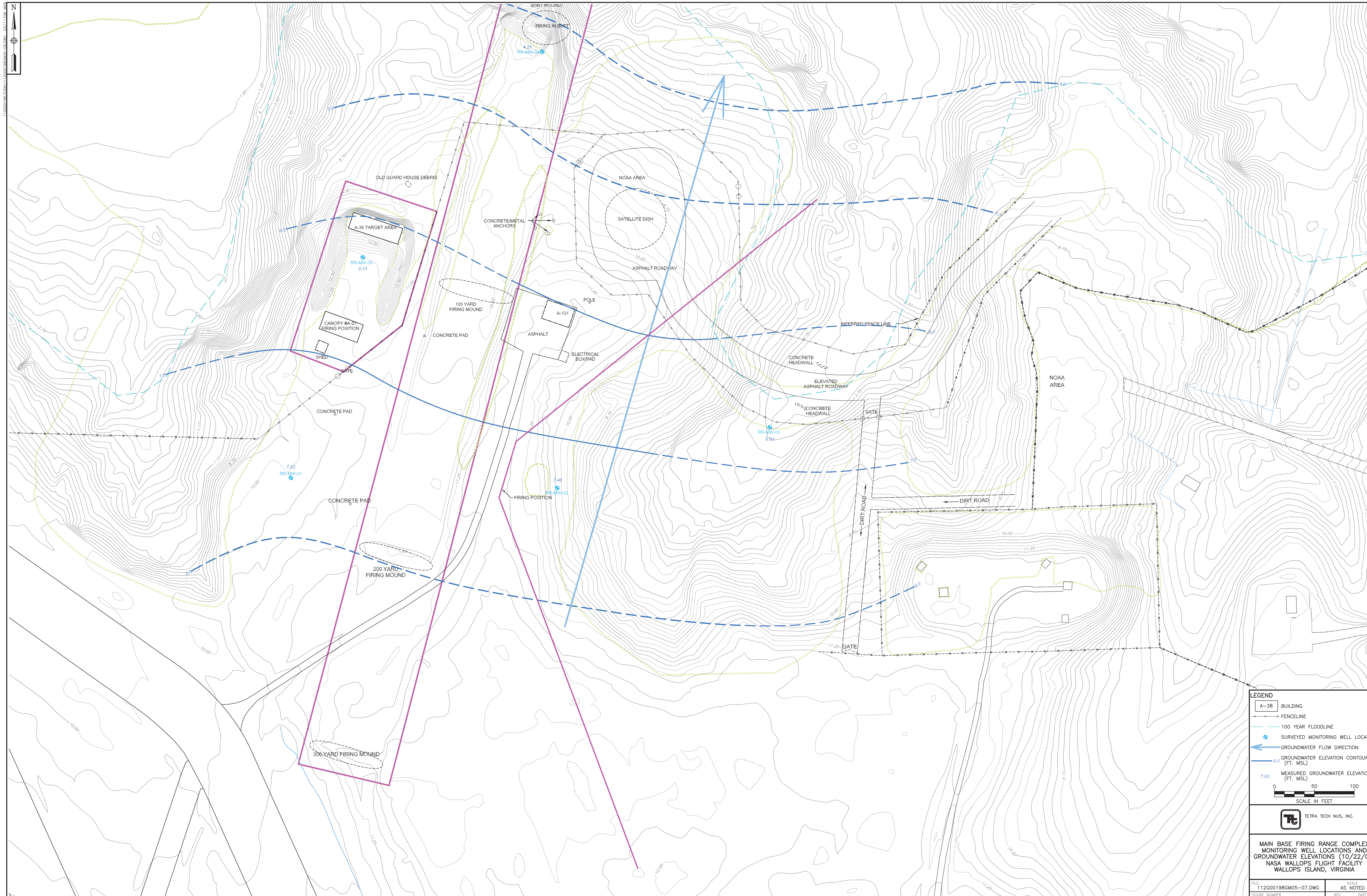


LEGEND

A-38	BUILDING
	FENCELINE
	100 YEAR FLOODLINE
	SURVEYED MONITORING WELL LOCATION
	GROUNDWATER FLOW DIRECTION
6.0	GROUNDWATER ELEVATION CONTOUR (FT. MSL)
7.83	MEASURED GROUNDWATER ELEVATION (FT. MSL)

0 50 100

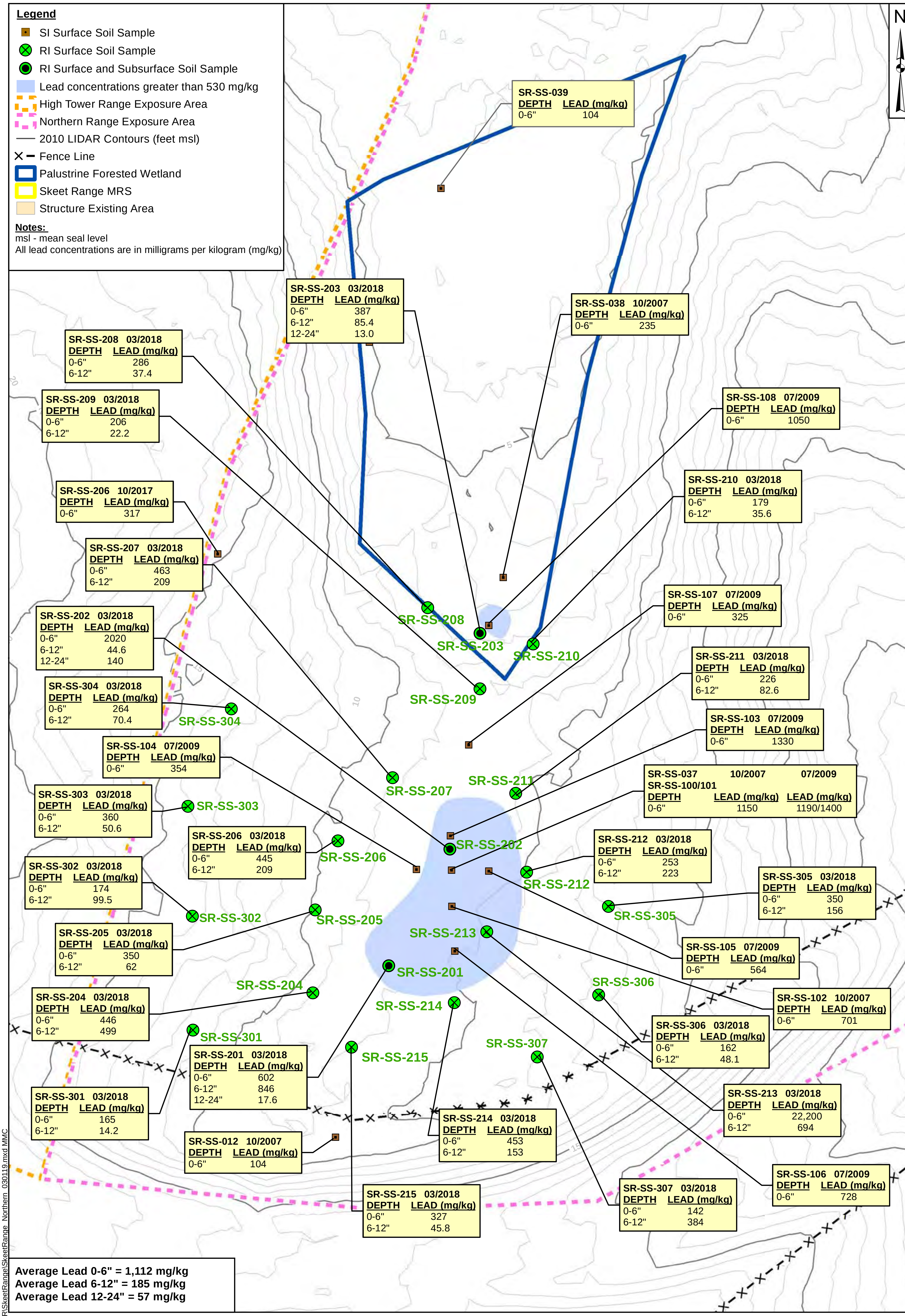
SCALE IN FEET

TETRA TECH NUS, INC.

MAIN BASE FIRING RANGE COMPLEX
MONITORING WELL LOCATIONS AND
GROUNDWATER ELEVATIONS (10/22/07)
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE:	SCALE
112G00198GM05-07.DWG	AS NOTED

FIGURE NUMBER	REV	DATE
FIGURE 5	0	03/11/08



NOR: G:\GIS_files\NASA WI\MXD\MBFR\SkeetRange\SkeetRange_Northern_030119.mxd MMC

Base Map:
Aerial Imagery 2013 ESRI map service

LEAD ANALYTICAL RESULTS
NORTHERN RANGE AREA
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

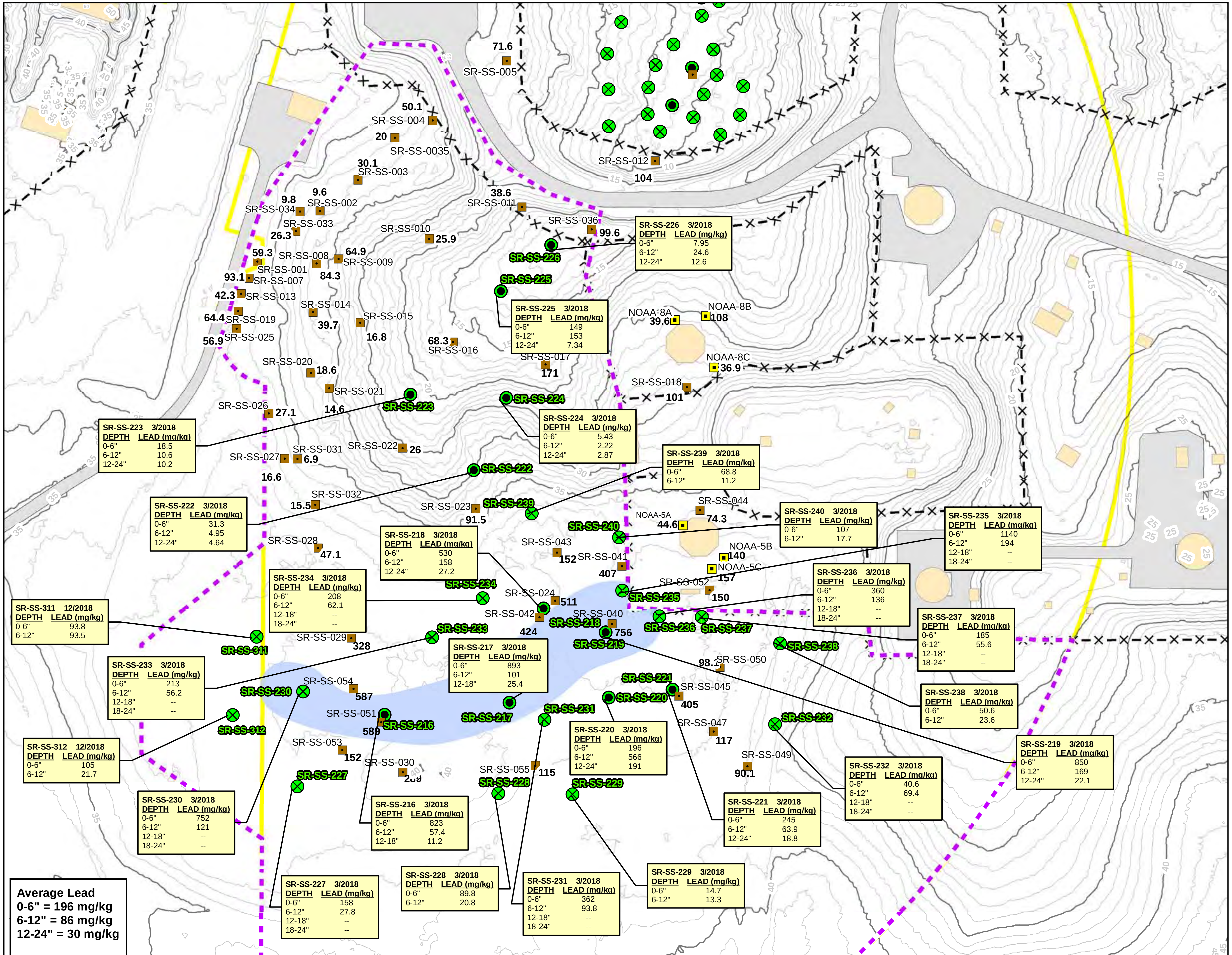
0 30 60 Feet

FIGURE: 4-1

Prepared For: NASA

Prepared By: TETRA TECH

Date: 7/17/2019



Legend

- NOAA Soil Sample
- SI Surface Soil Sample
- RI Surface and Subsurface Soil Sample
- RI Surface Soil Sample
- 2010 LIDAR Contours (feet msl)
- Fence Line
- Lead concentrations greater than 750 mg/kg
- Southern Range Exposure Area
- Structure Existing Area
- Skeet Range MRS

Notes:
- # Next to sample label indicates Lead Concentration (mg/kg)
- 750 mg/kg represents the not to exceed lead concentration for plants
- msl - mean seal level

N

0 50 100 200 Feet

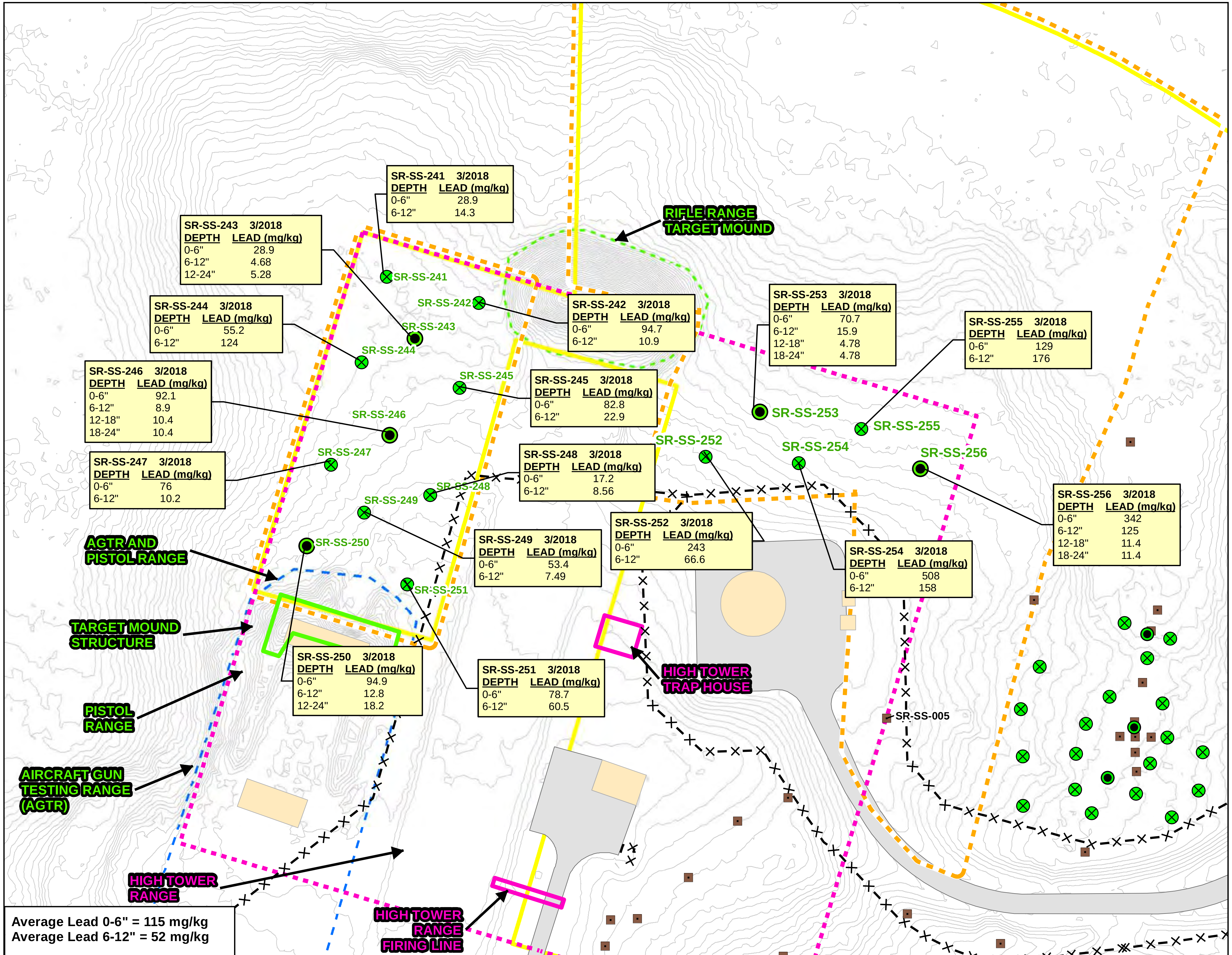
FIGURE 4-2
LEAD ANALYTICAL RESULTS
SOUTHERN RANGE AREA
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

TETRA TECH | 8/15/2019

Aerial Imagery 2013 ESRI map service

Coordinate System: North American Datum, 1983 VA South, Meters

NOR: G:\GIS_files\NASA WI\MXD\MBFR\SkeetRange\SkeetRange_southern_pro_022819.mxd MMC



Legend

- RI Surface and Subsurface Soil Sample
- RI Surface Soil Sample
- SI Surface Soil Sample
- Fence Line
- High Tower Range Exposure Area
- 2010 LIDAR Contours (feet msl)
- Structure Existing Area
- Rifle Range Target Mound
- Approximate AGTR Boundary
- High Tower Range
- Skeet Range MRS

Notes:
- msl - mean seal level
- All lead concentrations in milligrams per kilogram (mg/kg)

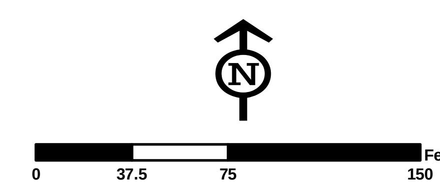


FIGURE 4-3
LEAD ANALYTICAL RESULTS
HIGH TOWER RANGE AREA
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

TETRA TECH | 7/17/2019

Aerial Imagery 2013 ESRI map service

Coordinate System: North American Datum, 1983 VA South, Meters

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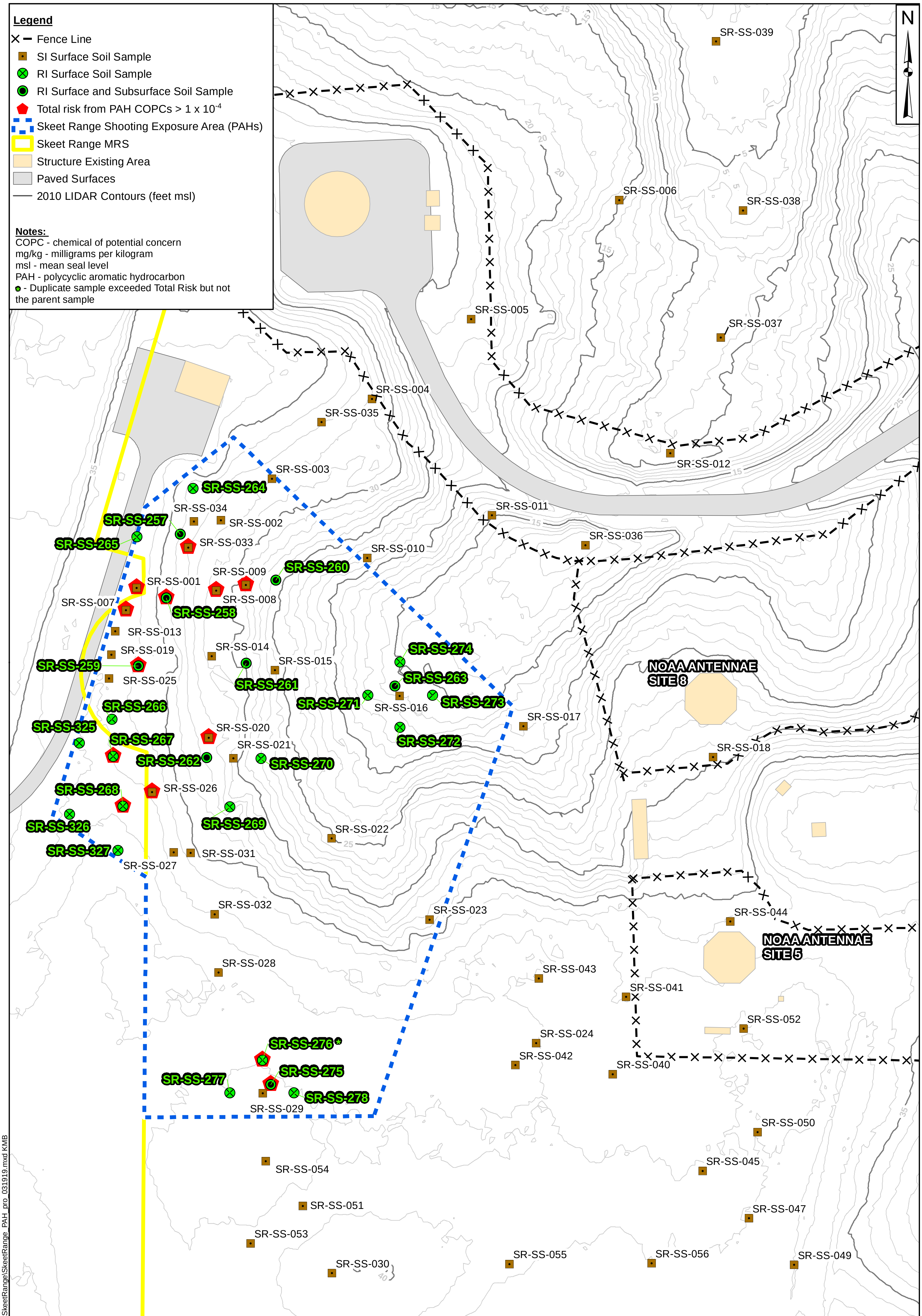


NOR: G:\GIS_files\NASA WIMXDIMBFR\SkeetRange\SkeetRange_PAH_pro_031919.mxd KMB

Base Map:
Aerial Imagery 2013 ESRI map service

TOTAL RISK SUMMARY
SKEET RANGE SHOOTING AREA
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

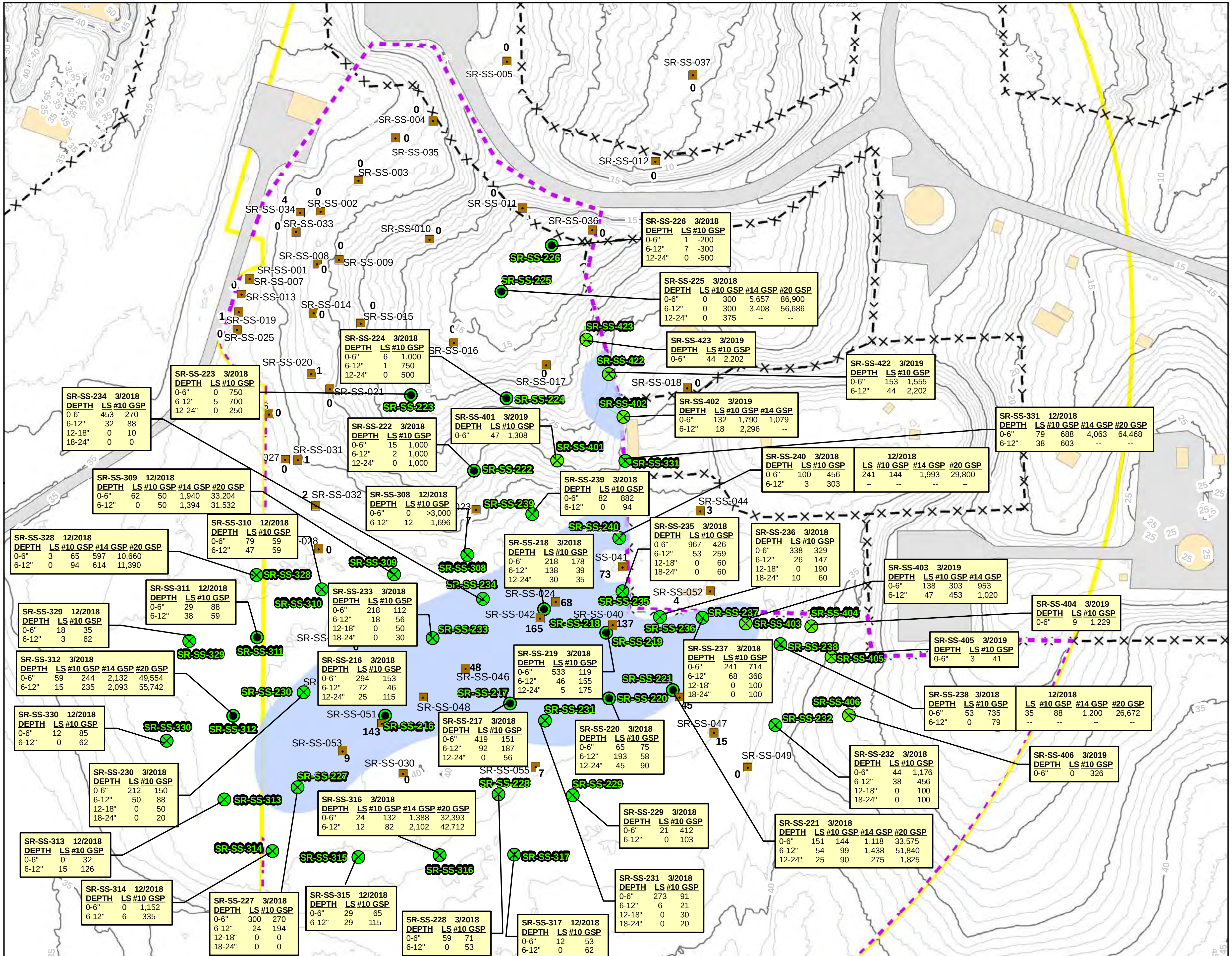
Feet
0 70 140

FIGURE: 4-4

Prepared For: NASA

Prepared By: TETRA TECH

Date: 7/17/2019



Legend

- SI Surface Soil Sample
- RI Surface and Subsurface Soil Sample
- RI Surface Soil Sample
- 2010 LIDAR Contours (feet msl)
- Fence Line
- Exceeds 100 LS/Foot^2
- Southern Range Exposure Area
- Structure Existing Area
- Skeet Range MRS

Notes:

- msl - mean seal level
- LS- Lead Shot
- GSP- Grit Sized Particles
- #10 GSP retained #10 sieve
- # - Lead Shot (LS) counts

N

0 50 100 200 Feet

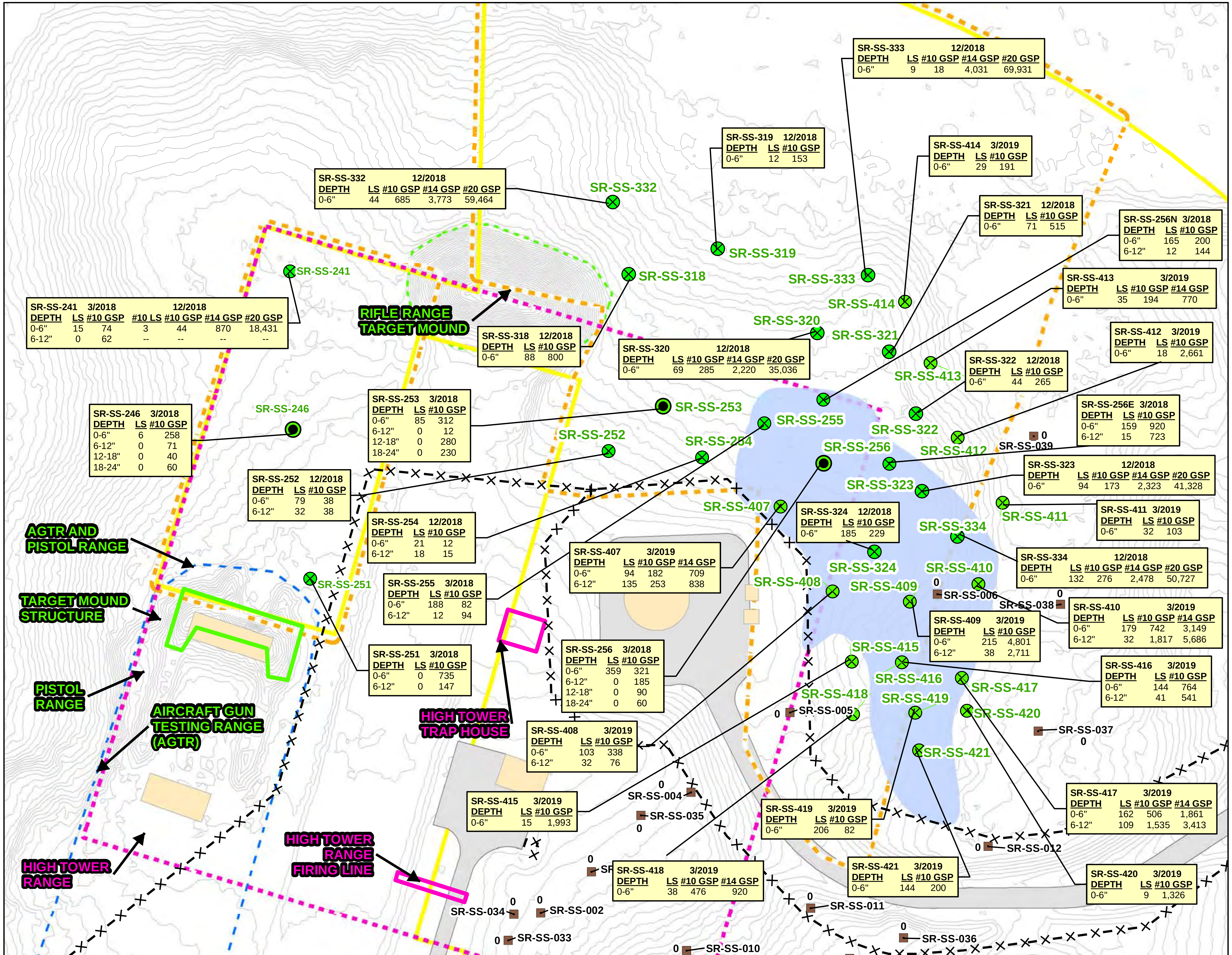
FIGURE 4-5
LEAD SHOT RESULTS
SOUTHERN RANGE AREA
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

TETRA TECH | 8/15/2019

Aerial Imagery 2013 ESRI map service

Coordinate System: North American Datum, 1983 VA South, Meters

NOR: G:\GIS_files\NASA WI\MXD\MBFR\SkeetRange\SkeetRange_southern_proLSTag_032019.mxd MMC



Legend

- RI Surface and Subsurface Soil Sample
- RI Surface Soil Sample
- SI Surface Soil Sample
- Fence Line
- 2010 LIDAR Contours (feet msl)
- High Tower Range Exposure Area
- Structure Existing Area
- Rifle Range Target Mound
- Approximate AGTR Boundary
- High Tower Range
- Skeet Range MRS
- Exceeds 100 LS/Foot [2]

Notes:
- **LS- Lead Sample**
- **GSP - Grit Sized Particles**
- **#10 GSP retained #10 sieve**

Feet
0 30 60 120

FIGURE 4-6
LEAD SHOT RESULTS
HIGH TOWER RANGE AREA
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

TETRA TECH | 7/17/2019

Aerial Imagery 2013 ESRI map service

Coordinate System: North American Datum, 1983 VA South, Meters

NOR: G:\GIS_files\NASA WI\MXD\MBFR\SkeetRange\SR_pro_hightower_LSTag032019.mxd MMC

TABLE 3-1
SOIL SAMPLE SUMMARY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA
PAGE 1 OF 4

				LABORATORY ANALYSIS			SIEVE ANALYSIS			
Sample Location	**Sample ID**	**Sample Date**	**Depth (Feet BGS)**	**Lead**	**PAHs**	**Grain Size**	**#10**	**#14**	**#20**	**#35**
NORTHERN RANGE AREA										
SR-SS-201	SR-SS-201-0006	3/22/2018	0 - 0.5	X						
	SR-SS-201-0612	3/22/2018	0.5 - 1	X						
	SR-SB-201-1224	3/22/2018	1 - 2	X						
SR-SS-202	SR-SS-202-0006	3/22/2018	0 - 0.5	X						
	SR-SS-202-0612	3/22/2018	0.5 - 1	X						
	SR-SB-202-1224	3/22/2018	1 - 2	X						
SR-SS-203	SR-SS-203-0006	3/22/2018	0 - 0.5	X						
	SR-SS-203-0006-D	3/22/2018	0 - 0.5	X						
	SR-SS-203-0612	3/22/2018	0.5 - 1	X						
	SR-SB-203-1224	3/22/2018	1 - 2	X						
SR-SS-204	SR-SS-204-0006	3/22/2018	0 - 0.5	X						
	SR-SS-204-0612	3/22/2018	0.5 - 1	X						
SR-SS-205	SR-SS-205-0006	3/22/2018	0 - 0.5	X						
	SR-SS-205-0612	3/22/2018	0.5 - 1	X						
SR-SS-206	SR-SS-206-0006	3/22/2018	0 - 0.5	X						
	SR-SS-206-0612	3/22/2018	0.5 - 1	X						
SR-SS-207	SR-SS-207-0006	3/22/2018	0 - 0.5	X						
	SR-SS-207-0612	3/22/2018	0.5 - 1	X						
SR-SS-208	SR-SS-208-0006	3/22/2018	0 - 0.5	X						
	SR-SS-208-0612	3/22/2018	0.5 - 1	X						
SR-SS-209	SR-SS-209-0006	3/22/2018	0 - 0.5	X						
	SR-SS-209-0612	3/22/2018	0.5 - 1	X						
SR-SS-210	SR-SS-210-0006	3/22/2018	0 - 0.5	X						
	SR-SS-210-0612	3/22/2018	0.5 - 1	X						
SR-SS-211	SR-SS-211-0006	3/22/2018	0 - 0.5	X						
	SR-SS-211-0612	3/22/2018	0.5 - 1	X						
SR-SS-212	SR-SS-212-0006	3/22/2018	0 - 0.5	X						
	SR-SS-212-0612	3/22/2018	0.5 - 1	X						
SR-SS-213	SR-SS-213-0006	3/22/2018	0 - 0.5	X						
	SR-SS-213-0612	3/22/2018	0.5 - 1	X						
SR-SS-214	SR-SS-214-0006	3/22/2018	0 - 0.5	X						
	SR-SS-214-0612	3/22/2018	0.5 - 1	X						
SR-SS-215	SR-SS-215-0006	3/22/2018	0 - 0.5	X						
	SR-SS-215-0612	3/22/2018	0.5 - 1	X						
SR-SS-301	SR-SS-301-0006	12/19/2018	0 - 0.5	X						
	SR-SS-301-0612	12/19/2018	0.5 - 1	X						
SR-SS-302	SR-SS-302-0006	12/19/2018	0 - 0.5	X						
	SR-SS-302-0612	12/19/2018	0.5 - 1	X						
	SR-SS-302-0612-D	12/19/2018	0.5 - 1	X						
SR-SS-303	SR-SS-303-0006	12/19/2018	0 - 0.5	X						
	SR-SS-303-0612	12/19/2018	0.5 - 1	X						
SR-SS-304	SR-SS-304-0006	12/19/2018	0 - 0.5	X						
	SR-SS-304-0612	12/19/2018	0.5 - 1	X						
SR-SS-305	SR-SS-305-0006	12/19/2018	0 - 0.5	X						
	SR-SS-305-0612	12/19/2018	0.5 - 1	X						
SR-SS-306	SR-SS-306-0006	12/19/2018	0 - 0.5	X						
	SR-SS-306-0612	12/19/2018	0.5 - 1	X						
SR-SS-307	SR-SS-307-0006	12/19/2018	0 - 0.5	X						
	SR-SS-307-0612	12/19/2018	0.5 - 1	X						
SOUTHERN RANGE AREA										
SR-SS-216	SR-SS-216-0006	3/21/2018	0 - 0.5	X			X			
	SR-SS-216-0612	3/21/2018	0.5 - 1	X			X			
	SR-SB-216-1224	3/22/2018	1 - 2	X			X			
SR-SS-217	SR-SS-217-0006	3/21/2018	0 - 0.5	X			X			
	SR-SS-217-0006-D	3/21/2018	0 - 0.5	X						
	SR-SS-217-0612	3/21/2018	0.5 - 1	X			X			
	SR-SB-217-1224	3/22/2018	1 - 2	X			X			
SR-SS-218	SR-SS-218-0006	3/20/2018	0 - 0.5	X			X			
	SR-SS-218-0612	3/20/2018	0.5 - 1	X			X			
	SR-SB-218-1224	3/21/2018	1 - 2	X			X			
SR-SS-219	SR-SS-219-0006	3/20/2018	0 - 0.5	X			X			
	SR-SS-219-0612	3/20/2018	0.5 - 1	X			X			
	SR-SB-219-1224	3/21/2018	1 - 2	X			X			
SR-SS-220	SR-SS-220-0006	3/21/2018	0 - 0.5	X			X			
	SR-SS-220-0612	3/21/2018	0.5 - 1	X			X			
	SR-SB-220-1224	3/22/2018	1 - 2	X			X			
SR-SS-221	SR-SS-221-0006	3/21/2018	0 - 0.5	X			X	X	X	X
	SR-SS-221-0612	3/21/2018	0.5 - 1	X			X	X	X	X
	SR-SB-221-1224	3/22/2018	1 - 2	X			X	X	X	X
SR-SS-222	SR-SS-222-0006	3/20/2018	0 - 0.5	X			X			
	SR-SS-222-0612	3/20/2018	0.5 - 1	X			X			
	SR-SB-222-1224	3/21/2018	1 - 2	X			X			
	SR-SB-222-1224-D	3/21/2018	1 - 2	X						
SR-SS-223	SR-SS-223-0006	3/20/2018	0 - 0.5	X			X			
	SR-SS-223-0612	3/20/2018	0.5 - 1	X			X			
	SR-SB-223-1224	3/21/2018	1 - 2	X			X			
	SR-SB-223-1224-D	3/21/2018	1 - 2	X						
SR-SS-224	SR-SS-224-0006	3/20/2018	0 - 0.5	X			X			
	SR-SS-224-0612	3/20/2018	0.5 - 1	X			X			
	SR-SS-224-0612-D	3/20/2018	0.5 - 1	X						
	SR-SB-224-1224	3/21/2018	1 - 2	X			X			
SR-SS-225	SR-SS-225-0006	3/20/2018	0 - 0.5	X		X	X	X	X	X
	SR-SS-225-0612	3/20/2018	0.5 - 1	X		X	X	X	X	X
	SR-SB-225-1224	3/21/2018	1 - 2	X		X	X			
SR-SS-226	SR-SS-226-0006	3/19/2018	0 - 0.5	X			X			
	SR-SS-226-0006-D	3/19/2018	0 - 0.5	X						
	SR-SS-226-0612	3/19/2018	0.5 - 1	X			X			
	SR-SB-226-1224	3/20/2018	1 - 2	X			X			

TABLE 3-1
SOIL SAMPLE SUMMARY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA
PAGE 2 OF 4

				LABORATORY ANALYSIS			SIEVE ANALYSIS			
Sample Location	**Sample ID**	**Sample Date**	**Depth (Feet BGS)**	**Lead**	**PAHs**	**Grain Size**	**#10**	**#14**	**#20**	**#35**
SOUTHERN RANGE AREA (continued)										
SR-SS-227	SR-SS-227-0006	3/26/2018	0 - 0.5	X		X	X			
	SR-SS-227-0612	3/26/2018	0.5 - 1	X		X	X			
	SR-SS-227-0612-D	3/26/2018	0.5 - 1	X						
	SR-SB-227-1218	3/26/2018	1 - 1.5				X			
	SR-SB-227-1824	3/26/2018	1.5 - 2				X			
SR-SS-228	SR-SS-228-0006	3/26/2018	0 - 0.5	X			X			
	SR-SS-228-0612	3/26/2018	0.5 - 1	X			X			
SR-SS-229	SR-SS-229-0006	3/26/2018	0 - 0.5	X			X			
	SR-SS-229-0612	3/26/2018	0.5 - 1	X			X			
SR-SS-230	SR-SS-230-0006	3/26/2018	0 - 0.5	X			X			
	SR-SS-230-0612	3/26/2018	0.5 - 1	X			X			
	SR-SB-230-1218	3/26/2018	1 - 1.5				X			
	SR-SB-230-1824	3/26/2018	1.5 - 2				X			
SR-SS-231	SR-SS-231-0006	3/27/2018	0 - 0.5	X			X			
	SR-SS-231-0612	3/27/2018	0.5 - 1	X			X			
	SR-SB-231-1218	3/28/2018	1 - 1.5				X			
	SR-SB-231-1824	3/28/2018	1.5 - 2				X			
SR-SS-232	SR-SS-232-0006	3/26/2018	0 - 0.5	X			X			
	SR-SS-232-0612	3/26/2018	0.5 - 1	X			X			
	SR-SB-232-1218	3/26/2018	1 - 1.5				X			
	SR-SB-232-1824	3/26/2018	1.5 - 2				X			
SR-SS-233	SR-SS-233-0006	3/27/2018	0 - 0.5	X			X			
	SR-SS-233-0612	3/27/2018	0.5 - 1	X			X			
	SR-SS-233-0612-D	3/27/2018	0.5 - 1	X						
	SR-SB-233-1218	3/28/2018	1 - 1.5				X			
	SR-SB-233-1824	3/28/2018	1.5 - 2				X			
SR-SS-234	SR-SS-234-0006	3/27/2018	0 - 0.5	X			X			
	SR-SS-234-0612	3/27/2018	0.5 - 1	X			X			
	SR-SB-234-1218	3/28/2018	1 - 1.5				X			
	SR-SB-234-1824	3/28/2018	1.5 - 2				X			
SR-SS-235	SR-SS-235-0006	3/27/2018	0 - 0.5	X			X			
	SR-SS-235-0612	3/27/2018	0.5 - 1	X			X			
	SR-SB-235-1218	3/28/2018	1 - 1.5				X			
	SR-SB-235-1824	3/28/2018	1.5 - 2				X			
SR-SS-236	SR-SS-236-0006	3/27/2018	0 - 0.5	X			X			
	SR-SS-236-0612	3/27/2018	0.5 - 1	X			X			
	SR-SB-236-1218	3/28/2018	1 - 1.5				X			
	SR-SB-236-1824	3/28/2018	1.5 - 2				X			
SR-SS-237	SR-SS-237-0006	3/27/2018	0 - 0.5	X			X			
	SR-SS-237-0612	3/27/2018	0.5 - 1	X			X			
	SR-SB-237-1218	3/28/2018	1 - 1.5				X			
	SR-SB-237-1824	3/28/2018	1.5 - 2				X			
SR-SS-238	SR-SS-238-0006	3/26/2018	0 - 0.5	X			X			
	SR-SS-238-0006	12/17/2018	0 - 0.5				X	X	X	
	SR-SS-238-0612	3/26/2018	0.5 - 1	X			X			
SR-SS-239	SR-SS-239-0006	3/26/2018	0 - 0.5	X			X			
	SR-SS-239-0612	3/26/2018	0.5 - 1	X			X			
SR-SS-240	SR-SS-240-0006	3/26/2018	0 - 0.5	X			X			
	SR-SS-240-0006	12/17/2018	0 - 0.5				X	X	X	
	SR-SS-240-0612	3/26/2018	0.5 - 1	X			X			
SR-SS-257	SR-SS-257-0006	3/22/2018	0 - 0.5		X					
	SR-SS-257-0612	3/22/2018	0.5 - 1		X					
	SR-SB-257-1224	3/22/2018	1 - 2		X					
SR-SS-258	SR-SS-258-0006	3/22/2018	0 - 0.5		X					
	SR-SS-258-0612	3/22/2018	0.5 - 1		X					
	SR-SB-258-1224	3/22/2018	1 - 2		X					
SR-SS-259	SR-SS-259-0006	3/22/2018	0 - 0.5		X					
	SR-SS-259-0612	3/22/2018	0.5 - 1		X					
	SR-SS-259-0612-D	3/22/2018	0.5 - 1		X					
	SR-SS-259-1224	3/22/2018	1 - 2		X					
SR-SS-260	SR-SS-260-0006	3/22/2018	0 - 0.5		X					
	SR-SS-260-0612	3/22/2018	0.5 - 1		X					
	SR-SS-260-0612-D	3/22/2018	0.5 - 1		X					
	SR-SS-260-1224	3/22/2018	1 - 2		X					
SR-SS-261	SR-SS-261-0006	3/22/2018	0 - 0.5		X					
	SR-SS-261-0612	3/22/2018	0.5 - 1		X					
	SR-SS-261-1224	3/22/2018	1 - 2		X					
SR-SS-262	SR-SS-262-0006	3/22/2018	0 - 0.5		X					
	SR-SS-262-0612	3/22/2018	0.5 - 1		X					
	SR-SS-262-1224	3/22/2018	1 - 2		X					
SR-SS-263	SR-SS-263-0006	3/22/2018	0 - 0.5		X					
	SR-SS-263-0612	3/22/2018	0.5 - 1		X					
	SR-SS-263-1224	3/22/2018	1 - 2		X					
SR-SS-264	SR-SS-264-0006	3/22/2018	0 - 0.5		X					
SR-SS-265	SR-SS-265-0006	3/22/2018	0 - 0.5		X					
SR-SS-266	SR-SS-266-0006	3/22/2018	0 - 0.5		X					
SR-SS-267	SR-SS-267-0006	3/22/2018	0 - 0.5		X					
	SR-SS-267-0006-D	3/22/2018	0 - 0.5		X					
SR-SS-268	SR-SS-268-0006	3/22/2018	0 - 0.5		X					
SR-SS-269	SR-SS-269-0006	3/22/2018	0 - 0.5		X					
SR-SS-270	SR-SS-270-0006	3/22/2018	0 - 0.5		X					
SR-SS-271	SR-SS-271-0006	3/22/2018	0 - 0.5		X					
SR-SS-272	SR-SS-272-0006	3/22/2018	0 - 0.5		X					
SR-SS-273	SR-SS-273-0006	3/22/2018	0 - 0.5		X					
SR-SS-274	SR-SS-274-0006	3/22/2018	0 - 0.5		X					
SR-SS-275	SR-SS-275-0006	3/22/2018	0 - 0.5		X					
	SR-SS-275-0612	3/22/2018	0.5 - 1		X					
	SR-SS-275-1224	3/22/2018	1 - 2		X					
SR-SS-276	SR-SS-276-0006	3/22/2018	0 - 0.5		X					
	SR-SS-276-0006-D	3/22/2018	0 - 0.5		X					

TABLE 3-1
SOIL SAMPLE SUMMARY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

				LABORATORY ANALYSIS			SIEVE ANALYSIS			
Sample Location	**Sample ID**	**Sample Date**	**Depth (Feet BGS)**	**Lead**	**PAHs**	**Grain Size**	**#10**	**#14**	**#20**	**#35**
SOUTHERN RANGE AREA (continued)										
SR-SS-277	SR-SS-277-0006	3/22/2018	0 - 0.5		X					
SR-SS-278	SR-SS-278-0006	3/22/2018	0 - 0.5		X					
SR-SS-308	SR-SS-308-0006	12/18/2018	0 - 0.5				X			
	SR-SS-308-0612	12/18/2018	0.5 - 1				X			
SR-SS-309	SR-SS-309-0006	12/17/2018	0 - 0.5				X	X	X	
	SR-SS-309-0612	12/17/2018	0.5 - 1				X	X	X	
SR-SS-310	SR-SS-310-0006	12/18/2018	0 - 0.5				X			
	SR-SS-310-0612	12/18/2018	0.5 - 1				X			
SR-SS-311	SR-SB-311-0006	12/18/2018	0 - 0.5	X			X			
	SR-SB-311-0612	12/18/2018	0.5 - 1	X			X			
SR-SS-312	SR-SS-312-0006	12/17/2018	0 - 0.5	X			X	X	X	
	SR-SS-312-0612	12/17/2018	0.5 - 1	X			X	X	X	
	SR-SS-312-0612-D	12/17/2018	0.5 - 1	X						
SR-SS-313	SR-SS-313-0006	12/18/2018	0 - 0.5				X			
	SR-SS-313-0612	12/18/2018	0.5 - 1				X			
SR-SS-314	SR-SS-314-0006	12/18/2018	0 - 0.5				X			
	SR-SS-314-0612	12/18/2018	0.5 - 1				X			
SR-SS-315	SR-SB-315-0006	12/18/2018	0 - 0.5				X			
	SR-SB-315-0612	12/18/2018	0.5 - 1				X			
SR-SS-316	SR-SS-316-0006	12/17/2018	0 - 0.5				X	X	X	
	SR-SS-316-0612	12/17/2018	0.5 - 1				X	X	X	
SR-SS-317	SR-SS-317-0006	12/18/2018	0 - 0.5				X			
	SR-SS-317-0612	12/18/2018	0.5 - 1				X			
SR-SS-325	SR-SS-325-0006	12/20/2018	0 - 0.5		X					
	SR-SS-325-0006-D	12/20/2018	0 - 0.5		X					
SR-SS-326	SR-SS-326-0006	12/20/2018	0 - 0.5		X					
SR-SS-327	SR-SS-327-0006	12/20/2018	0 - 0.5		X					
SR-SS-328	SR-SS-328-0006	12/19/2018	0 - 0.5				X	X	X	
	SR-SS-328-0612	12/19/2018	0.5 - 1				X	X	X	
SR-SS-329	SR-SS-329-0006	12/19/2018	0 - 0.5				X			
	SR-SS-329-0612	12/19/2018	0.5 - 1				X			
SR-SS-330	SR-SS-330-0006	12/19/2018	0 - 0.5				X			
	SR-SS-330-0612	12/19/2018	0.5 - 1				X			
SR-SS-331	SR-SS-331-0006	12/19/2018	0 - 0.5				X	X	X	
	SR-SS-331-0612	12/19/2018	0.5 - 1				X			
SR-SS-401	SR-SS-401-0006	3/26/2019	0 - 0.5				X			
SR-SS-402	SR-SS-402-0006	3/26/2019	0 - 0.5				X	X		
	SR-SS-402-0612	3/26/2019	0.5 - 1				X			
SR-SS-403	SR-SS-403-0006	3/26/2019	0 - 0.5				X	X		
	SR-SS-403-0612	3/26/2019	0.5 - 1				X	X		
SR-SS-404	SR-SS-404-0006	3/26/2019	0 - 0.5				X			
SR-SS-405	SR-SS-405-0006	3/26/2019	0 - 0.5				X			
SR-SS-406	SR-SS-406-0006	3/26/2019	0 - 0.5				X			
SR-SS-422	SR-SS-422-0006	3/27/2019	0 - 0.5				X			
	SR-SS-422-0612	3/27/2019	0.5 - 1				X			
SR-SS-423	SR-SS-423-0006	3/27/2019	0 - 0.5				X			
HIGH TOWER RANGE AREA										
SR-SS-241	SR-SS-241-0006	3/28/2018	0 - 0.5	X			X			
	SR-SS-241-0006	12/18/2018	0 - 0.5				X	X	X	
	SR-SS-241-0612	3/28/2018	0.5 - 1	X			X			
SR-SS-242	SR-SS-242-0006	3/23/2018	0 - 0.5	X						
	SR-SS-242-0006-D	3/23/2018	0 - 0.5	X						
	SR-SS-242-0612	3/23/2018	0.5 - 1	X						
SR-SS-243	SR-SS-243-0006	3/24/2018	0 - 0.5	X						
	SR-SS-243-0612	3/24/2018	0.5 - 1	X						
	SR-SS-243-1224	3/24/2018	1 - 2	X						
SR-SS-244	SR-SS-244-0006	3/24/2018	0 - 0.5	X						
	SR-SS-244-0612	3/24/2018	0.5 - 1	X						
SR-SS-245	SR-SS-245-0006	3/23/2018	0 - 0.5	X						
	SR-SS-245-0612	3/23/2018	0.5 - 1	X						
SR-SS-246	SR-SS-246-0006	3/23/2018	0 - 0.5	X		X	X			
	SR-SS-246-0612	3/23/2018	0.5 - 1	X		X	X			
	SR-SB-246-1218	3/28/2018	1 - 1.5				X			
	SR-SB-246-1824	3/28/2018	1.5 - 2				X			
	SR-SB-246-1224	3/23/2018	1 - 2	X		X				
	SR-SB-246-1224-D	3/23/2018	1 - 2	X						
SR-SS-247	SR-SS-247-0006	3/23/2018	0 - 0.5	X						
	SR-SS-247-0612	3/23/2018	0.5 - 1	X						
SR-SS-248	SR-SS-248-0006	3/23/2018	0 - 0.5	X						
	SR-SS-248-0612	3/23/2018	0.5 - 1	X						
SR-SS-249	SR-SS-249-0006	3/23/2018	0 - 0.5	X						
	SR-SS-249-0612	3/23/2018	0.5 - 1	X						
SR-SS-250	SR-SS-250-0006	3/23/2018	0 - 0.5	X						
	SR-SS-250-0612	3/23/2018	0.5 - 1	X						
	SR-SS-250-1224	3/23/2018	1 - 2	X						
SR-SS-251	SR-SS-251-0006	3/28/2018	0 - 0.5	X			X			
	SR-SS-251-0612	3/28/2018	0.5 - 1	X			X			
SR-SS-252	SR-SS-252-0006	3/23/2018	0 - 0.5	X						
	SR-SS-252-0006	12/18/2018	0 - 0.5				X			
	SR-SB-252-0612	3/23/2018	0.5 - 1	X						
	SR-SB-252-0612	12/18/2018	0.5 - 1				X			
SR-SS-253	SR-SS-253-0006	3/28/2018	0 - 0.5	X			X			
	SR-SS-253-0006-D	3/28/2018	0 - 0.5	X						
	SR-SS-253-0612	3/28/2018	0.5 - 1	X			X			
	SR-SB-253-1218	3/28/2018	1 - 1.5				X			
	SR-SB-253-1824	3/28/2018	1.5 - 2				X			
	SR-SB-253-1224	3/28/2018	1 - 2	X						

TABLE 3-1
SOIL SAMPLE SUMMARY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

				LABORATORY ANALYSIS			SIEVE ANALYSIS			
Sample Location	**Sample ID**	**Sample Date**	**Depth (Feet BGS)**	**Lead**	**PAHs**	**Grain Size**	**#10**	**#14**	**#20**	**#35**
HIGH TOWER RANGE AREA (continued)										
SR-SS-254	SR-SS-254-0006	3/23/2018	0 - 0.5	X						
	SR-SS-254-0006	12/18/2018	0 - 0.5				X			
	SR-SB-254-0612	3/23/2018	0.5 - 1	X						
	SR-SB-254-0612	12/18/2018	0.5 - 1				X			
SR-SS-255	SR-SS-255-0006	3/23/2018	0 - 0.5	X			X			
	SR-SS-255-0612	3/23/2018	0.5 - 1	X			X			
	SR-SS-255-0612-D	3/23/2018	0.5 - 1	X						
SR-SS-256	SR-SS-256-0006	3/28/2018	0 - 0.5	X			X			
	SR-SS-256-0612	3/28/2018	0.5 - 1	X			X			
	SR-SB-256-1218	3/28/2018	1 - 1.5				X			
	SR-SB-256-1824	3/28/2018	1.5 - 2				X			
	SR-SB-256-1224	3/28/2018	1 - 2	X						
SR-SS-256N	SR-SS-256N-0006	3/28/2018	0 - 0.5				X			
	SR-SS-256N-0612	3/28/2018	0.5 - 1				X			
SR-SS-256E	SR-SS-256E-0006	3/28/2018	0 - 0.5				X			
	SR-SS-256E-0612	3/28/2018	0.5 - 1				X			
SR-SS-318	SR-SS-318-0006	12/18/2018	0 - 0.5				X			
SR-SS-319	SR-SB-319-0006	12/18/2018	0 - 0.5				X			
SR-SS-320	SR-SS-320-0006	12/18/2018	0 - 0.5				X	X	X	
SR-SS-321	SR-SB-321-0006	12/18/2018	0 - 0.5				X			
SR-SS-322	SR-SS-322-0006	12/18/2018	0 - 0.5				X			
SR-SS-323	SR-SB-323-0006	12/18/2018	0 - 0.5				X	X	X	
SR-SS-324	SR-SS-324-0006	12/18/2018	0 - 0.5				X			
SR-SS-332	SR-SS-332-0006	12/19/2018	0 - 0.5				X	X	X	
SR-SS-333	SR-SS-333-0006	12/19/2018	0 - 0.5				X	X	X	
SR-SS-334	SR-SS-334-0006	12/19/2018	0 - 0.5				X	X	X	
SR-SS-407	SR-SS-407-0006	3/26/2019	0 - 0.5				X	X		
	SR-SS-407-0612	3/26/2019	0.5 - 1				X	X		
SR-SS-408	SR-SS-408-0006	3/26/2019	0 - 0.5				X			
	SR-SS-408-0612	3/26/2019	0.5 - 1				X			
SR-SS-409	SR-SS-409-0006	3/26/2019	0 - 0.5				X			
	SR-SS-409-0612	3/27/2019	0.5 - 1				X			
SR-SS-410	SR-SS-410-0006	3/26/2019	0 - 0.5				X	X		
	SR-SS-410-0612	3/27/2019	0.5 - 1				X	X		
SR-SS-411	SR-SS-411-0006	3/26/2019	0 - 0.5				X			
SR-SS-412	SR-SS-412-0006	3/26/2019	0 - 0.5				X			
SR-SS-413	SR-SS-413-0006	3/26/2019	0 - 0.5				X	X		
SR-SS-414	SR-SS-414-0006	3/26/2019	0 - 0.5				X			
SR-SS-415	SR-SS-415-0006	3/27/2019	0 - 0.5				X			
SR-SS-416	SR-SS-416-0006	3/27/2019	0 - 0.5				X			
	SR-SS-416-0612	3/27/2019	0.5 - 1				X			
SR-SS-417	SR-SS-417-0006	3/27/2019	0 - 0.5				X	X		
	SR-SS-417-0612	3/27/2019	0.5 - 1				X	X		
SR-SS-418	SR-SS-418-0006	3/27/2019	0 - 0.5				X	X		
SR-SS-419	SR-SS-419-0006	3/27/2019	0 - 0.5				X			
SR-SS-420	SR-SS-420-0006	3/27/2019	0 - 0.5				X			
SR-SS-421	SR-SS-421-0006	3/27/2019	0 - 0.5				X			

Notes:

D Duplicate Sample
PAHs Polycyclic Aromatic Hydrocarbons

TABLE 4-1
LEAD ANALYTICAL SUMMARY
SKEET RANGE MRS - NORTHERN RANGE AREA
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

		SR-SS-006	SR-SS-012	SR-SS-037	SR-SS-038	SR-SS-039	SR-SS-100	SR-SS-100-D	SR-SS-102	SR-SS-103	SR-SS-104	SR-SS-105	SR-SS-106
SAMPLE		SR-SS-006-000.5	SR-SS-012-000.5	SR-SS-037-000.5	SR-SS-038-000.5	SR-SS-039-000.5	SR-SS-100-000.5	SR-SS-100-000.5	SR-SS-102-000.5	SR-SS-103-000.5	SR-SS-104-000.5	SR-SS-105-000.5	SR-SS-106-000.5
SAMPLE DEPTH (inches)	PRG[1]	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
SAMPLE DATE		10/19/2007	10/18/2007	10/19/2007	10/19/2007	10/19/2007	7/20/2009	7/20/2009	7/20/2009	7/20/2009	7/20/2009	7/20/2009	7/20/2009
LEAD (mg/kg)	530	317	104	**1150**	235	104 J	**1190**	**1400**	**701**	**1330**	354	**564**	**728**

		SR-SS-107	SR-SS-108	SR-SS-201			SR-SS-202			SR-SS-203			
SAMPLE		SR-SS-107-000.5	SR-SS-108-000.5	SR-SS-201-0006	SR-SS-201-0612	SR-SB-201-1224	SR-SS-202-0006	SR-SS-202-0612	SR-SB-202-1224	SR-SS-203-0006	SR-SS-203-0006-D	SR-SS-203-0612	SR-SB-203-1224
SAMPLE DEPTH (inches)	PRG[1]	0 - 6	0 - 6	0 - 6	6 - 12	12 - 24	0 - 6	6 - 12	12 - 24	0 - 6	0 - 6	6 - 12	12 - 24
SAMPLE DATE		7/20/2009	7/20/2009	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018
LEAD (mg/kg)	530	325	**1050**	**602**	**846**	17.6	**2020**	44.6	140	387	411	85.4	13

		SR-SS-204		SR-SS-205		SR-SS-206		SR-SS-207		SR-SS-208		SR-SS-209	
SAMPLE		SR-SS-204-0006	SR-SS-204-0612	SR-SS-205-0006	SR-SS-205-0612	SR-SS-206-0006	SR-SS-206-0612	SR-SS-207-0006	SR-SS-207-0612	SR-SS-208-0006	SR-SS-208-0612	SR-SS-209-0006	SR-SS-209-0612
SAMPLE DEPTH (inches)	PRG[1]	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12
SAMPLE DATE		03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018
LEAD (mg/kg)	530	446	499	350	62	445	209	463	209	286	37.4	206	22.2

		SR-SS-210		SR-SS-211		SR-SS-212		SR-SS-213		SR-SS-214		SR-SS-215	
SAMPLE		SR-SS-210-0006	SR-SS-210-0612	SR-SS-211-0006	SR-SS-211-0612	SR-SS-212-0006	SR-SS-212-0612	SR-SS-213-0006	SR-SS-213-0612	SR-SS-214-0006	SR-SS-214-0612	SR-SS-215-0006	SR-SS-215-0612
SAMPLE DEPTH (inches)	PRG[1]	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12
SAMPLE DATE		03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018	03/22/2018
LEAD (mg/kg)	530	179	35.6	226	82.6	253	223	**22200**	**694**	453	153	327	45.8

		SR-SS-301		SR-SS-302			SR-SS-303		SR-SS-304		SR-SS-305	
SAMPLE		SR-SS-301-0006	SR-SS-301-0612	SR-SS-302-0006	SR-SS-302-0612	SR-SS-302-0612-D	SR-SS-303-0006	SR-SS-303-0612	SR-SS-304-0006	SR-SS-304-0612	SR-SS-305-0006	SR-SS-305-0612
SAMPLE DEPTH (inches)	PRG[1]	0 - 6	6 - 12	0 - 6	6 - 12	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12
SAMPLE DATE		12/19/2018	12/19/2018	12/19/2018	12/19/2018	12/19/2018	12/19/2018	12/19/2018	12/19/2018	12/19/2018	12/19/2018	12/19/2018
LEAD (mg/kg)	530	165 J	14.2 J	174 J	99.5 J	92.2 J	360 J	50.6 J	264 J	70.4 J	350 J	156 J

		SR-SS-306		SR-SS-307	
SAMPLE		SR-SS-306-0006	SR-SS-306-0612	SR-SS-307-0006	SR-SS-307-0612
SAMPLE DEPTH (inches)	PRG[1]	0 - 6	6 - 12	0 - 6	6 - 12
SAMPLE DATE		12/19/2018	12/19/2018	12/19/2018	12/19/2018
LEAD (mg/kg)	530	162 J	48.1 J	142 J	384 J

Notes:

-D Duplicate sample
mg/kg Miligrams per kilogram
PRG Preliminary Remediation Goal
[1] 530 mg/kg represents the not-to-exceed lead PRG for sediment invertebrates. The arithmetic mean PRG for across each exposure area is set at 200 mg/kg for human health and 240 mg/kg for plants.
Bolded and shaded values indicate exceedances of the not-to-exceed lead PRG of 530 mg/kg

Average Lead Concentration		Average Lead Concentration (without not-to-exceed values)	
0 - 6 inches	1112 mg/kg	0 - 6 inches	284 mg/kg
6 - 12 inches	185 mg/kg	6 - 12 inches	127 mg/kg
12 - 24 inches	57 mg/kg	12 - 24 inches	57 mg/kg

TABLE 4-2
LEAD ANALYTICAL SUMMARY
SKEET RANGE MRS - SOUTHERN RANGE AREA
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

		SR-SS-001	SR-SS-002	SR-SS-003	SR-SS-004	SR-SS-007		SR-SS-008	SR-SS-009	SR-SS-010	SR-SS-011	SR-SS-013	SR-SS-014
SAMPLE	PRG(1)	SR-SS-001-000.5	SR-SS-002-000.5	SR-SS-003-000.5	SR-SS-004-000.5	SR-SS-007-000.5	SR-SS-007-000.5-D	SR-SS-008-000.5	SR-SS-009-000.5	SR-SS-010-000.5	SR-SS-011-000.5	SR-SS-013-000.5	SR-SS-014-000.5
SAMPLE DEPTH		0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
SAMPLE DATE		10/19/2007	10/19/2007	10/19/2007	10/22/2007	10/22/2007	10/22/2007	10/22/2007	10/22/2007	10/22/2007	10/18/2007	10/22/2007	10/22/2007
LEAD (mg/kg)	750	59.3	9.6	30.1	50.1	93.9	97.5	84.3	64.9	25.9	38.6	42.3	39.7

		SR-SS-015	SR-SS-016	SR-SS-017	SR-SS-019	SR-SS-020		SR-SS-021	SR-SS-022	SR-SS-023	SR-SS-024	SR-SS-025	SR-SS-026
SAMPLE	PRG(1)	SR-SS-015-000.5	SR-SS-016-000.5	SR-SS-017-000.5	SR-SS-019-000.5	SR-SS-020-000.5	SR-SS-020-000.5-D	SR-SS-021-000.5	SR-SS-022-000.5	SR-SS-023-000.5	SR-SS-024-000.5	SR-SS-025-000.5	SR-SS-026-000.5
SAMPLE DEPTH		0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
SAMPLE DATE		10/22/2007	10/22/2007	10/22/2007	10/24/2007	10/24/2007	10/24/2007	10/25/2007	10/25/2007	10/25/2007	10/25/2007	10/24/2007	10/24/2007
LEAD (mg/kg)	750	16.8	68.3	171	64.4	16.6	18.6	14.6	26	91.5	511	56.9	27.1

		SR-SS-027	SR-SS-028	SR-SS-029	SR-SS-030	SR-SS-031	SR-SS-032	SR-SS-033	SR-SS-034	SR-SS-035	SR-SS-036	SR-SS-040
SAMPLE	PRG(1)	SR-SS-027-000.5	SR-SS-028-000.5	SR-SS-029-000.5	SR-SS-030-000.5	SR-SS-031-000.5	SR-SS-032-000.5	SR-SS-033-000.5	SR-SS-034-000.5	SR-SS-035-000.5	SR-SS-036-000.5	SR-SS-040-000.5
SAMPLE DEPTH		0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
SAMPLE DATE		10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/25/2007	10/24/2007	10/25/2007	10/18/2007	11/6/2007
LEAD (mg/kg)	750	16.6	47.1	328	289	6.9	15.5	26.3	9.8	20	99.6	**756**

		SR-SS-041		SR-SS-042	SR-SS-043	SR-SS-045	SR-SS-047	SR-SS-049	SR-SS-050	SR-SS-051	SR-SS-053	SR-SS-054	SR-SS-055
SAMPLE	PRG(1)	SR-SS-041-000.5	SR-SS-041-000.5-D	SR-SS-042-000.5	SR-SS-043-000.5	SR-SS-045-000.5	SR-SS-047-000.5	SR-SS-049-000.5	SR-SS-050-000.5	SR-SS-051-000.5	SR-SS-053-000.5	SR-SS-054-000.5	SR-SS-055-000.5
SAMPLE DEPTH		0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
SAMPLE DATE		11/6/2007	11/6/2007	11/6/2007	11/6/2007	11/6/2007	11/6/2007	11/6/2007	11/7/2007	11/7/2007	11/7/2007	11/7/2007	11/7/2007
LEAD (mg/kg)	750	398	407	424	152	405	117	90.1	98.1	589	152	587	115

		SR-SS-056	SR-SS-216			SR-SS-217				SR-SS-218		
SAMPLE	PRG(1)	SR-SS-056-000.5	SR-SS-216-0006	SR-SS-216-0612	SR-SB-216-1224	SR-SS-217-0006	SR-SS-217-0006-D	SR-SS-217-0612	SR-SB-217-1224	SR-SS-218-0006	SR-SS-218-0612	SR-SB-218-1224
SAMPLE DEPTH		0 - 6	0 - 6	6 - 12	12 - 24	0 - 6	0 - 6	6 - 12	12 - 24	0 - 6	6 - 12	12 - 24
SAMPLE DATE		11/7/2007	03/21/2018	03/21/2018	03/22/2018	03/21/2018	03/21/2018	03/21/2018	03/22/2018	03/20/2018	03/20/2018	03/21/2018
LEAD (mg/kg)	750	58.7	**823 J-**	57.4 J-	11.2	**893 J-**	**954 J-**	101 J-	25.4 J-	530	158	27.2 J-

		SR-SS-219			SR-SS-220			SR-SS-221		
SAMPLE	PRG(1)	SR-SS-219-0006	SR-SS-219-0612	SR-SB-219-1224	SR-SS-220-0006	SR-SS-220-0612	SR-SB-220-1224	SR-SS-221-0006	SR-SS-221-0612	SR-SB-221-1224
SAMPLE DEPTH		0 - 6	6 - 12	12 - 24	0 - 6	6 - 12	12 - 24	0 - 6	6 - 12	12 - 24
SAMPLE DATE		03/20/2018	03/20/2018	03/21/2018	03/21/2018	03/21/2018	03/22/2018	03/21/2018	03/21/2018	03/22/2018
LEAD (mg/kg)	750	**850**	169	22.1 J-	196 J-	566 J-	191 J-	245 J-	63.9 J-	18.8 J-

		SR-SS-222				SR-SS-223				SR-SS-224			
SAMPLE	PRG(1)	SR-SS-222-0006	SR-SS-222-0612	SR-SB-222-1224	SR-SB-222-1224-D	SR-SS-223-0006	SR-SS-223-0612	SR-SB-223-1224	SR-SB-223-1224-D	SR-SS-224-0006	SR-SS-224-0612	SR-SS-224-0612-D	SR-SB-224-1224
SAMPLE DEPTH		0 - 6	6 - 12	12 - 24	12 - 24	0 - 6	6 - 12	12 - 24	12 - 24	0 - 6	6 - 12	6 - 12	12 - 24
SAMPLE DATE		03/20/2018	03/20/2018	03/21/2018	03/21/2018	03/20/2018	03/20/2018	03/21/2018	03/21/2018	03/20/2018	03/20/2018	03/20/2018	03/21/2018
LEAD (mg/kg)	750	31.3	4.95	4.64 J-	5.37 J-	18.5	10.6	10.2	5.79 J-	5.43	2.22	2.3	2.87 J-

		SR-SS-225			SR-SS-226				SR-SS-227			SR-SS-228	
SAMPLE	PRG(1)	SR-SS-225-0006	SR-SS-225-0612	SR-SB-225-1224	SR-SS-226-0006	SR-SS-226-0006-D	SR-SS-226-0612	SR-SS-226-1224	SR-SS-227-0006	SR-SS-227-0612	SR-SS-227-0612-D	SR-SS-228-0006	SR-SS-228-0612
SAMPLE DEPTH		0 - 6	6 - 12	12 - 24	0 - 6	0 - 6	6 - 12	12 - 24	0 - 6	6 - 12	6 - 12	0 - 6	6 - 12
SAMPLE DATE		03/20/2018	03/20/2018	03/21/2018	03/19/2018	03/19/2018	03/19/2018	03/20/2018	03/26/2018	03/26/2018	03/26/2018	03/26/2018	03/26/2018
LEAD (mg/kg)	750	149	153	7.34 J-	7.95	8.09	24.6	12.6	158 J	27.8 J	28 J	89.8 J	20.8 J

		SR-SS-229		SR-SS-230		SR-SS-231		SR-SS-232		SR-SS-233		
SAMPLE	PRG(1)	SR-SS-229-0006	SR-SS-229-0612	SR-SS-230-0006	SR-SS-230-0612	SR-SS-231-0006	SR-SS-231-0612	SR-SS-232-0006	SR-SS-232-0612	SR-SS-233-0006	SR-SS-233-0612	SR-SS-233-0612-D
SAMPLE DEPTH		0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12	6 - 12
SAMPLE DATE		03/26/2018	03/26/2018	03/26/2018	03/26/2018	03/27/2018	03/27/2018	03/26/2018	03/26/2018	03/27/2018	03/27/2018	03/27/2018
LEAD (mg/kg)	750	14.7 J	13.3 J	**752 J**	121 J	362 J	93.8 J	40.6 J	69.4 J	213 J	56.2 J	56.1

		SR-SS-234		SR-SS-235		SR-SS-236		SR-SS-237		SR-SS-238		SR-SS-239	
SAMPLE	PRG(1)	SR-SS-234-0006	SR-SS-234-0612	SR-SS-235-0006	SR-SS-235-0612	SR-SS-236-0006	SR-SS-236-0612	SR-SS-237-0006	SR-SS-237-0612	SR-SS-238-0006	SR-SS-238-0612	SR-SS-239-0006	SR-SS-239-0612
SAMPLE DEPTH		0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12
SAMPLE DATE		03/27/2018	03/27/2018	03/27/2018	03/27/2018	03/27/2018	03/27/2018	03/27/2018	03/27/2018	03/26/2018	03/26/2018	03/27/2018	03/27/2018
LEAD (mg/kg)	750	208	62.1	**1140**	194	360	136	185	55.6	50.6 J	23.6 J	68.8	11.2

TABLE 4-2
LEAD ANALYTICAL SUMMARY
SKEET RANGE MRS - SOUTHERN RANGE AREA
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

		SR-SS-240		**SR-SS-311**		**SR-SS-312-0006**	
SAMPLE	**PRG[1]**	**SR-SS-240-0006**	**SR-SS-240-0612**	**SR-SS-311-0006**	**SR-SS-311-0612**	**SR-SS-312-0006**	**SR-SS-312-0612**
SAMPLE DEPTH		**0 - 6**	**6 - 12**	**0 - 6**	**6 - 12**	**0 - 6**	**6 - 12**
SAMPLE DATE		**03/27/2018**	**03/27/2018**	**12/18/2018**	**12/18/2018**	**12/17/2018**	**12/17/2018**
LEAD (mg/kg)	750	107	17.7	93.8 J	93.5 J	105 J	21.7 J

Notes:
-D Duplicate sample
mg/kg Miligrams per kilogram
PRG Preliminary Remediation Goal
[1] 750 mg/kg represents the not-to-exceed lead PRG for plants. The arithmetic mean PRG for across each exposure area is set at 200 mg/kg for human health and 240 mg/kg for plants.
Bolded and shaded values indicate exceedances of the not-to-exceed lead PRG of 750 mg/kg

Average Lead Concentration

0 - 6 inches	196 mg/kg
6 - 12 inches	86 mg/kg
12 - 24 inches	30 mg/kg

TABLE 4-3
LEAD ANALYTICAL SUMMARY
SKEET RANGE MRS - HIGH TOWER RANGE AREA
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

		SR-SS-005	SR-SS-241		SR-SS-242			SR-SS-243			SR-SS-244	
SAMPLE	PRG[1]	SR-SS-005-0006	SR-SS-241-0006	SR-SS-241-0612	SR-SS-242-0006	SR-SS-242-0006-D	SR-SS-242-0612	SR-SS-243-0006	SR-SS-243-0612	SR-SS-243-1224	SR-SS-244-0006	SR-SS-244-0612
SAMPLE DEPTH (inches)		0 - 6	0 - 6	6 - 12	0 - 6	0 - 6	6 - 12	0 - 6	6 - 12	12 - 24	0 - 6	6 - 12
SAMPLE DATE		10/18/2007	03/28/2018	03/28/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018
LEAD (mg/kg)	750	28.9	28.9	14.3	94.7 J	81 J	10.9 J	28.9 J	4.68 J	5.28 J	55.2	124

		SR-SS-245		SR-SS-246				SR-SS-247		SR-SS-248		SR-SS-249	
SAMPLE	PRG[1]	SR-SS-245-0006	SR-SS-245-0612	SR-SS-246-0006	SR-SS-246-0612	SR-SB-246-1224	SR-SB-246-1224-D	SR-SS-247-0006	SR-SS-247-0612	SR-SS-248-0006	SR-SS-248-0612	SR-SS-249-0006	SR-SS-249-0612
SAMPLE DEPTH (inches)		0 - 6	6 - 12	0 - 6	6 - 12	12 - 24	12 - 24	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	6 - 12
SAMPLE DATE		03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018
LEAD (mg/kg)	750	82.8	22.9	92.1	8.9	10.4	11.1	76 J	10.2 J	17.2	8.56 J	53.4 J	7.49 J

		SR-SS-250			SR-SS-251		SR-SS-252		SR-SS-253			
SAMPLE	PRG[1]	SR-SS-250-0006	SR-SS-250-0612	SR-SB-250-1224	SR-SS-251-0006	SR-SS-251-0612	SR-SS-252-0006	SR-SS-252-0612	SR-SS-253-0006	SR-SS-253-0006-D	SR-SS-253-0612	SR-SB-253-1224
SAMPLE DEPTH (inches)		0 - 6	6 - 12	12 - 24	0 - 6	6 - 12	0 - 6	6 - 12	0 - 6	0 - 6	6 - 12	12 - 24
SAMPLE DATE		03/23/2018	03/23/2018	03/23/2018	03/28/2018	03/28/2018	03/23/2018	03/23/2018	03/28/2018	03/28/2018	03/28/2018	03/28/2018
LEAD (mg/kg)	750	94.9 J	12.8 J	18.2 J	7.87	60.5	243	66.6	70.7	61.3	15.9	4.78

		SR-SS-254		SR-SS-255			SR-SS-256		
SAMPLE	PRG[1]	SR-SS-254-0006	SR-SS-254-0612	SR-SS-255-0006	SR-SS-255-0612	SR-SS-255-0612-D	SR-SS-256-0006	SR-SS-256-0612	SR-SB-256-1224
SAMPLE DEPTH (inches)		0 - 6	6 - 12	0 - 6	6 - 12	6 - 12	0 - 6	6 - 12	12 - 24
SAMPLE DATE		03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/23/2018	03/28/2018	03/28/2018	03/28/2018
LEAD (mg/kg)	750	508	158	129	176 J	105 J	342	125	11.4

Notes:

-D Duplicate sample
mg/kg Miligrams per kilogram
PRG Preliminary Remediation Goal
(1) 750 mg/kg represents the not-to-exceed lead PRG for plants. The arithmetic mean PRG for across each exposure area is set at 200 mg/kg for human health and 240 mg/kg for plants.
Bolded and shaded values indicate exceedances of the not-to-exceed lead PRG of 750 mg/kg

Average Lead Concentration	
0 - 6 inches	115 mg/kg
6 - 12 inches	52 mg/kg
12 - 24 inches	10 mg/kg

TABLE 4-4
PAH ANALYTICAL SUMMARY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

		SR-SS-257			**SR-SS-258**			**SR-SS-259**				**SR-SS-260**
Sample	**Residential RSL November 2018**[1]	**SR-SS-257-0006**	**SR-SS-257-0612**	**SR-SB-257-1224**	**SR-SS-258-0006**	**SR-SS-258-0612**	**SR-SB-258-1224**	**SR-SS-259-0006**	**SR-SS-259-0612**	**SR-SS-259-061-D**	**SR-SB-259-1224**	**SR-SS-260-0006**
Sample Date		**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**
PAH (µg/kg)												
Benzo(A)Anthracene	1,100	890	17 J	30	**22,000**	710	190	**14,000**	**2,000**	**1,300**	33	**3,800**
Benzo(A)Pyrene	110	**1,000**	20 J	35	**22,000**	**770**	**180**	**17,000**	**2,200**	**1,500**	40	**3,900**
Benzo(B)Fluoranthene	1,100	**1,500**	29	52	**31,000**	**1,100**	240	**25,000**	**2,900**	**2,200**	56	**5,200**
Benzo(K)Fluoranthene	11,000	470	5.7 J	14 J	**13,000**	370	92	7,800	1,200	760	14 J	2,200
Chrysene	110,000	1,100	19 J	36	27,000	860	220	18,000	2,400	1,700	38	4,400
Dibenzo(A,H)Anthracene	110	**250**	4.4 J	11 J	**5,100**	**200**	44	**6,000**	**600**	**300**	12 J	**1,000**
Indeno(1,2,3-CD)Pyrene	1,100	840	23	42	**18,000**	830	150	**20,000**	**1,900**	950	46	**3,500**
POINT RISK												
Benzo(A)Anthracene	1,100	8.1E-07	1.5E-08	2.7E-08	2.0E-05	6.5E-07	1.7E-07	1.3E-05	1.8E-06	1.2E-06	3.0E-08	3.5E-06
Benzo(A)Pyrene	110	9.1E-06	1.8E-07	3.2E-07	2.0E-04	7.0E-06	1.6E-06	1.5E-04	2.0E-05	1.4E-05	3.6E-07	3.5E-05
Benzo(B)Fluoranthene	1,100	1.4E-06	2.6E-08	4.7E-08	2.8E-05	1.0E-06	2.2E-07	2.3E-05	2.6E-06	2.0E-06	5.1E-08	4.7E-06
Benzo(K)Fluoranthene	11,000	4.3E-08	5.2E-10	1.3E-09	1.2E-06	3.4E-08	8.4E-09	7.1E-07	1.1E-07	6.9E-08	1.3E-09	2.0E-07
Chrysene	110,000	1.0E-08	1.7E-10	3.3E-10	2.5E-07	7.8E-09	2.0E-09	1.6E-07	2.2E-08	1.5E-08	3.5E-10	4.0E-08
Dibenzo(A,H)Anthracene	110	2.3E-06	4.0E-08	1.0E-07	4.6E-05	1.8E-06	4.0E-07	5.5E-05	5.5E-06	2.7E-06	1.1E-07	9.1E-06
Indeno(1,2,3-CD)Pyrene	1,100	7.6E-07	2.1E-08	3.8E-08	1.6E-05	7.5E-07	1.4E-07	1.8E-05	1.7E-06	8.6E-07	4.2E-08	3.2E-06
TOTAL POINT RISK		**1.4E-05**	**2.9E-07**	**5.3E-07**	**3.1E-04**	**1.1E-05**	**2.6E-06**	**2.6E-04**	**3.2E-05**	**2.0E-05**	**6.0E-07**	**5.6E-05**

Notes:

PAH Polycyclic aromatic hydrocarbon
µg/kg micrograms per kilogram
-D Duplicate sample
J Estimated value
1) If sample result was non-detect (U qualifier), 1/2 the detection limit was used for point risk calculation.
2) The seven PAHs in this table were determined to be risk drivers based on the risk ratio conducted during the Site Investigation (2008) and subsequent changes to the RSLs (through November 2018) due to updated toxicity values.
3) Total point risks calculated using the Residential Regional Screening Levels (RSLs) from November 2018 for each PAH identified as a risk driver.

Bolded and shaded values indicate exceedances of either the RSL or Total Point Risk of 1.0E-04

TABLE 4-4
PAH ANALYTICAL SUMMARY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

		SR-SS-260			**SR-SS-261**			**SR-SS-262**			**SR-SS-263**		
Sample	**Residential RSL November 2018[1]**	**SR-SS-260-0612**	**SR-SS-260-0612-D**	**SR-SB-260-1224**	**SR-SS-261-0006**	**SR-SS-261-0612**	**SR-SB-261-1224**	**SR-SS-262-0006**	**SR-SS-262-0612**	**SR-SB-262-1224**	**SR-SS-263-0006**	**SR-SS-263-0612**	**SR-SB-263-1224**
Sample Date		**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**
PAH (µg/kg)													
Benzo(A)Anthracene	1,100	450	350	25	550	16 J	3.9 J	**1,500**	69	24 M	6.2 J	98	56
Benzo(A)Pyrene	110	**550**	**420**	30	**660**	25	4.2 J	**1,700**	77	25 M	6.5 J	83	61
Benzo(B)Fluoranthene	1,100	740	600	43	880	33	6.1 J	**2,400**	110	40 M	11 J	120	85 M
Benzo(K)Fluoranthene	11,000	270	200	10 J	330	7.4 J	10 U	810	37	8.6 JM	11 U	39	29
Chrysene	110,000	550	440	27	660	18 J	10 U	1,900	80	26 M	3 J	110	65
Dibenzo(A,H)Anthracene	110	**160**	**110**	7.2 J	**180**	7.8 J	10 U	**460**	22	6.7 J	11 U	21 J	14 J
Indeno(1,2,3-CD)Pyrene	1,100	520	390	32	560	30	4.2 J	**1,600**	84	22	7 J	71	58 M
POINT RISK													
Benzo(A)Anthracene	1,100	4.1E-07	3.2E-07	2.3E-08	5.0E-07	1.5E-08	3.5E-09	1.4E-06	6.3E-08	2.2E-08	5.6E-09	8.9E-08	5.1E-08
Benzo(A)Pyrene	110	5.0E-06	3.8E-06	2.7E-07	6.0E-06	2.3E-07	3.8E-08	1.5E-05	7.0E-07	2.3E-07	5.9E-08	7.5E-07	5.5E-07
Benzo(B)Fluoranthene	1,100	6.7E-07	5.5E-07	3.9E-08	8.0E-07	3.0E-08	5.5E-09	2.2E-06	1.0E-07	3.6E-08	1.0E-08	1.1E-07	7.7E-08
Benzo(K)Fluoranthene	11,000	2.5E-08	1.8E-08	9.1E-10	3.0E-08	6.7E-10	4.5E-10	7.4E-08	3.4E-09	7.8E-10	5.0E-10	3.5E-09	2.6E-09
Chrysene	110,000	5.0E-09	4.0E-09	2.5E-10	6.0E-09	1.6E-10	4.5E-11	1.7E-08	7.3E-10	2.4E-10	2.7E-11	1.0E-09	5.9E-10
Dibenzo(A,H)Anthracene	110	1.5E-06	1.0E-06	6.5E-08	1.6E-06	7.1E-08	4.5E-08	4.2E-06	2.0E-07	6.1E-08	5.0E-08	1.9E-07	1.3E-07
Indeno(1,2,3-CD)Pyrene	1,100	4.7E-07	3.5E-07	2.9E-08	5.1E-07	2.7E-08	3.8E-09	1.5E-06	7.6E-08	2.0E-08	6.4E-09	6.5E-08	5.3E-08
TOTAL POINT RISK		**8.0E-06**	**6.1E-06**	**4.3E-07**	**9.5E-06**	**3.7E-07**	**9.7E-08**	**2.5E-05**	**1.1E-06**	**3.7E-07**	**1.3E-07**	**1.2E-06**	**8.7E-07**

Notes:

PAH Polycyclic aromatic hydrocarbon
µg/kg micrograms per kilogram
-D Duplicate sample
J Estimated value

1) If sample result was non-detect (U qualifier), 1/2 the detection limit was used for point risk calculation.
2) The seven PAHs in this table were determined to be risk drivers based on the risk ratio conducted during the Site Investigation (2008) and subsequent changes to the RSLs (through November 2018) due to updated toxicity values.
3) Total point risks calculated using the Residential Regional Screening Levels (RSLs) from November 2018 for each PAH identified as a risk driver.

Bolded and shaded values indicate exceedances of either the RSL or Total Point Risk of 1.0E-04

TABLE 4-4
PAH ANALYTICAL SUMMARY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

		SR-SS-264	SR-SS-265	SR-SS-266	SR-SS-267		SR-SS-268	SR-SS-269	SR-SS-270	SR-SS-271	SR-SS-272	SR-SS-273	SR-SS-274
Sample	**Residential RSL November 2018[1]**	**SR-SS-264-0006**	**SR-SS-265-0006**	**SR-SS-266-0006**	**SR-SS-267-0006**	**SR-SS-267-0006-D**	**SR-SS-268-0006**	**SR-SS-269-0006**	**SR-SS-270-0006**	**SR-SS-271-0006**	**SR-SS-272-0006**	**SR-SS-273-0006**	**SR-SS-274-0006**
Sample Date		**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**
PAH (µg/kg)													
Benzo(A)Anthracene	1,100	290	**1,400**	**6,000**	**38,000**	**60,000**	**9,600**	42	200	220	240	7 J	360
Benzo(A)Pyrene	110	**300**	**1,600**	**6,100**	**40,000**	**49,000**	**8,300**	67	**240**	**280**	**210**	9.2 J	**360**
Benzo(B)Fluoranthene	1,100	430	**2,300**	**8,600**	**52,000**	**72,000**	**11,000**	91	350	360	290	17 J	540
Benzo(K)Fluoranthene	11,000	140	720	2,800	**23,000**	**20,000**	4,400	28	110	140	86	10 U	170
Chrysene	110,000	370	1,800	7,300	47,000	61,000	11,000	55	250	270	250	3.7 J	440
Dibenzo(A,H)Anthracene	110	70	**410**	**1,500**	**11,000**	**12,000**	**1,900**	19 J	60	71	40	2 J	84
Indeno(1,2,3-CD)Pyrene	1,100	250	**1,400**	**5,400**	**34,000**	**37,000**	**6,800**	64	200	210	160	5.4 J	280
POINT RISK													
Benzo(A)Anthracene	1,100	2.6E-07	1.3E-06	5.5E-06	3.5E-05	5.5E-05	8.7E-06	3.8E-08	1.8E-07	2.0E-07	2.2E-07	6.4E-09	3.3E-07
Benzo(A)Pyrene	110	2.7E-06	1.5E-05	5.5E-05	3.6E-04	4.5E-04	7.5E-05	6.1E-07	2.2E-06	2.5E-06	1.9E-06	8.4E-08	3.3E-06
Benzo(B)Fluoranthene	1,100	3.9E-07	2.1E-06	7.8E-06	4.7E-05	6.5E-05	1.0E-05	8.3E-08	3.2E-07	3.3E-07	2.6E-07	1.5E-08	4.9E-07
Benzo(K)Fluoranthene	11,000	1.3E-08	6.5E-08	2.5E-07	2.1E-06	1.8E-06	4.0E-07	2.5E-09	1.0E-08	1.3E-08	7.8E-09	4.5E-10	1.5E-08
Chrysene	110,000	3.4E-09	1.6E-08	6.6E-08	4.3E-07	5.5E-07	1.0E-07	5.0E-10	2.3E-09	2.5E-09	2.3E-09	3.4E-11	4.0E-09
Dibenzo(A,H)Anthracene	110	6.4E-07	3.7E-06	1.4E-05	1.0E-04	1.1E-04	1.7E-05	1.7E-07	5.5E-07	6.5E-07	3.6E-07	1.8E-08	7.6E-07
Indeno(1,2,3-CD)Pyrene	1,100	2.3E-07	1.3E-06	4.9E-06	3.1E-05	3.4E-05	6.2E-06	5.8E-08	1.8E-07	1.9E-07	1.5E-07	4.9E-09	2.5E-07
TOTAL POINT RISK		**4.3E-06**	**2.3E-05**	**8.8E-05**	**5.8E-04**	**7.1E-04**	**1.2E-04**	**9.6E-07**	**3.4E-06**	**3.9E-06**	**2.9E-06**	**1.3E-07**	**5.1E-06**

Notes:

PAH Polycyclic aromatic hydrocarbon
µg/kg micrograms per kilogram
-D Duplicate sample
J Estimated value

1) If sample result was non-detect (U qualifier), 1/2 the detection limit was used for point risk calculation.
2) The seven PAHs in this table were determined to be risk drivers based on the risk ratio conducted during the Site Investigation (2008) and subsequent changes to the RSLs (through November 2018) due to updated toxicity values.
3) Total point risks calculated using the Residential Regional Screening Levels (RSLs) from November 2018 for each PAH identified as a risk driver.

Bolded and shaded values indicate exceedances of either the RSL or Total Point Risk of 1.0E-04

TABLE 4-4
PAH ANALYTICAL SUMMARY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

		SR-SS-275			SR-SS-276		SR-SS-277	SR-SS-278	SR-SS-325		SR-SS-326	SR-SS-327	SR-SS-001
Sample	**Residential RSL November 2018(1)**	**SR-SS-275-0006**	**SR-SS-275-0612**	**SR-SS-275-1224**	**SR-SS-276-0006**	**SR-SS-276-0006-D**	**SR-SS-277-0006**	**SR-SS-278-0006**	**SR-SS-325-0006**	**SR-SS-325-0006-D**	**SR-SS-326-0006**	**SR-SS-327-0006**	**SR-SS-001-000.5**
Sample Date		**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**03/22/2018**	**12/20/2018**	**12/20/2018**	**12/20/2018**	**12/20/2018**	**10/19/2007**
PAH (µg/kg)													
Benzo(A)Anthracene	1,100	**58,000**	**16,000**	58	810	**9,700**	**3,600**	**2,100**	1,100	890	38	53 J	**9,500**
Benzo(A)Pyrene	110	**48,000**	**14,000**	61	**770**	**8,300**	**2,800**	**1,800**	**1,000**	**1,000**	39	63 J	**14,000**
Benzo(B)Fluoranthene	1,100	**70,000**	**20,000**	85	**1,100**	**12,000**	**4,000**	**2,600**	**1,500**	**1,400**	66 J	94 J	**21,000**
Benzo(K)Fluoranthene	11,000	**18,000**	5,500	26	290	3,200	1,500	720	600	520	18 J	27 J	**9,000 J**
Chrysene	110,000	58,000	16,000	63	840	9,800	3,900	2,200	1,200	1,100	45	70 J	10,000
Dibenzo(A,H)Anthracene	110	**12,000**	**3,000**	16 J	**200**	**2,000**	**660**	**440**	**220 J**	**260 J**	21 J	26	**4,700**
Indeno(1,2,3-CD)Pyrene	1,100	**38,000**	**9,300**	60	640	**5,400**	**2,000**	**1,300**	860 J	740 J	56	100 J	**11,000 J**
POINT RISK													
Benzo(A)Anthracene	1,100	5.3E-05	1.5E-05	5.3E-08	7.4E-07	8.8E-06	3.3E-06	1.9E-06	1.0E-06	8.1E-07	3.5E-08	4.8E-08	8.6E-06
Benzo(A)Pyrene	110	4.4E-04	1.3E-04	5.5E-07	7.0E-06	7.5E-05	2.5E-05	1.6E-05	9.1E-06	9.1E-06	3.5E-07	5.7E-07	1.3E-04
Benzo(B)Fluoranthene	1,100	6.4E-05	1.8E-05	7.7E-08	1.0E-06	1.1E-05	3.6E-06	2.4E-06	1.4E-06	1.3E-06	6.0E-08	8.5E-08	1.9E-05
Benzo(K)Fluoranthene	11,000	1.6E-06	5.0E-07	2.4E-09	2.6E-08	2.9E-07	1.4E-07	6.5E-08	5.5E-08	4.7E-08	1.6E-09	2.5E-09	8.2E-07
Chrysene	110,000	5.3E-07	1.5E-07	5.7E-10	7.6E-09	8.9E-08	3.5E-08	2.0E-08	1.1E-08	1.0E-08	4.1E-10	6.4E-10	9.1E-08
Dibenzo(A,H)Anthracene	110	1.1E-04	2.7E-05	1.5E-07	1.8E-06	1.8E-05	6.0E-06	4.0E-06	2.0E-06	2.4E-06	1.9E-07	2.4E-07	4.3E-05
Indeno(1,2,3-CD)Pyrene	1,100	3.5E-05	8.5E-06	5.5E-08	5.8E-07	4.9E-06	1.8E-06	1.2E-06	7.8E-07	6.7E-07	5.1E-08	9.1E-08	1.0E-05
TOTAL POINT RISK		**7.0E-04**	**2.0E-04**	**8.9E-07**	**1.1E-05**	**1.2E-04**	**4.0E-05**	**2.6E-05**	**1.4E-05**	**1.4E-05**	**6.9E-07**	**1.0E-06**	**2.1E-04**

Notes:

PAH Polycyclic aromatic hydrocarbon
µg/kg micrograms per kilogram
-D Duplicate sample
J Estimated value

1) If sample result was non-detect (U qualifier), 1/2 the detection limit was used for point risk calculation.
2) The seven PAHs in this table were determined to be risk drivers based on the risk ratio conducted during the Site Investigation (2008) and subsequent changes to the RSLs (through November 2018) due to updated toxicity values.
3) Total point risks calculated using the Residential Regional Screening Levels (RSLs) from November 2018 for each PAH identified as a risk driver.

Bolded and shaded values indicate exceedances of either the RSL or Total Point Risk of 1.0E-04

TABLE 4-4
PAH ANALYTICAL SUMMARY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

		SR-SS-002	SR-SS-003	SR-SS-004	SR-SS-005	SR-SS-006	SR-SS-007		SR-SS-008	SR-SS-009	SR-SS-010	SR-SS-011	SR-SS-012
Sample	**Residential RSL November 2018[1]**	**SR-SS-002-000.5**	**SR-SS-003-000.5**	**SR-SS-004-000.5**	**SR-SS-005-000.5**	**SR-SS-006-000.5**	**SR-SS-007-000.5**	**SR-SS-007-000.5-D**	**SR-SS-008-000.5**	**SR-SS-009-000.5**	**SR-SS-010-000.5**	**SR-SS-011-000.5**	**SR-SS-012-000.5**
Sample Date		**10/19/2007**	**10/19/2007**	**10/22/2007**	**10/18/2007**	**10/22/2007**	**10/22/2007**	**10/22/2007**	**10/22/2007**	**10/22/2007**	**10/22/2007**	**10/18/2007**	**10/18/2007**
PAH (µg/kg)													
Benzo(A)Anthracene	1,100	890	800 J	15 J	22 J	3.7 J	**8,800 J**	**8,900 J**	**24,000**	**19,000 J**	22 J	6.5 J	11 J
Benzo(A)Pyrene	110	**990**	**780**	15 J	20 J	4.4 J	**8,700**	**9,200**	**28,000**	**17,000**	23	7.2 J	12 J
Benzo(B)Fluoranthene	1,100	**1,500**	**1,100**	20 J	20 J	6.5 J	**11,000**	**13,000**	**39,000**	**22,000**	34	8.3 J	13 J
Benzo(K)Fluoranthene	11,000	740 J	560 J	12 J	13 J	3.7 J	5,300 J	6,400 J	**21,000 J**	**12,000 J**	18 J	5 J	8 J
Chrysene	110,000	910	710	15 J	20 J	4.7 J	7,700	7,900	24,000	16,000	22	7.1 J	12 J
Dibenzo(A,H)Anthracene	110	**270**	**250**	12 J	20 U	21 U	**3,800 J**	**3,300 J**	**11,000**	**6,400 J**	14 J	21 U	21 U
Indeno(1,2,3-CD)Pyrene	1,100	830 J	670	14 J	16 J	5 J	**8,500**	**7,500**	**27,000 J**	**14,000**	25	5.8 J	9.7 J
POINT RISK													
Benzo(A)Anthracene	1,100	8.1E-07	7.3E-07	1.4E-08	2.0E-08	3.4E-09	8.0E-06	8.1E-06	2.2E-05	1.7E-05	2.0E-08	5.9E-09	1.0E-08
Benzo(A)Pyrene	110	9.0E-06	7.1E-06	1.4E-07	1.8E-07	4.0E-08	7.9E-05	8.4E-05	2.5E-04	1.5E-04	2.1E-07	6.5E-08	1.1E-07
Benzo(B)Fluoranthene	1,100	1.4E-06	1.0E-06	1.8E-08	1.8E-08	5.9E-09	1.0E-05	1.2E-05	3.5E-05	2.0E-05	3.1E-08	7.5E-09	1.2E-08
Benzo(K)Fluoranthene	11,000	6.7E-08	5.1E-08	1.1E-09	1.2E-09	3.4E-10	4.8E-07	5.8E-07	1.9E-06	1.1E-06	1.6E-09	4.5E-10	7.3E-10
Chrysene	110,000	8.3E-09	6.5E-09	1.4E-10	1.8E-10	4.3E-11	7.0E-08	7.2E-08	2.2E-07	1.5E-07	2.0E-10	6.5E-11	1.1E-10
Dibenzo(A,H)Anthracene	110	2.5E-06	2.3E-06	1.1E-07	1.8E-07	1.9E-07	3.5E-05	3.0E-05	1.0E-04	5.8E-05	1.3E-07	9.5E-08	9.5E-08
Indeno(1,2,3-CD)Pyrene	1,100	7.5E-07	6.1E-07	1.3E-08	1.5E-08	4.5E-09	7.7E-06	6.8E-06	2.5E-05	1.3E-05	2.3E-08	5.3E-09	8.8E-09
TOTAL POINT RISK		**1.4E-05**	**1.2E-05**	**2.9E-07**	**4.2E-07**	**2.5E-07**	**1.4E-04**	**1.4E-04**	**4.4E-04**	**2.6E-04**	**4.1E-07**	**1.8E-07**	**2.4E-07**

Notes:

- PAH Polycyclic aromatic hydrocarbon
- µg/kg micrograms per kilogram
- -D Duplicate sample
- J Estimated value

1) If sample result was non-detect (U qualifier), 1/2 the detection limit was used for point risk calculation.
2) The seven PAHs in this table were determined to be risk drivers based on the risk ratio conducted during the Site Investigation (2008) and subsequent changes to the RSLs (through November 2018) due to updated toxicity values.
3) Total point risks calculated using the Residential Regional Screening Levels (RSLs) from November 2018 for each PAH identified as a risk driver.

Bolded and shaded values indicate exceedances of either the RSL or Total Point Risk of 1.0E-04

		SR-SS-013	SR-SS-014	SR-SS-015	SR-SS-016	SR-SS-017	SR-SS-018	SR-SS-019	SR-SS-020		SR-SS-021	SR-SS-022	SR-SS-023
Sample	**Residential RSL November 2018(1)**	**SR-SS-013-000.5**	**SR-SS-014-000.5**	**SR-SS-015-000.5**	**SR-SS-016-000.5**	**SR-SS-017-000.5**	**SR-SS-018-000.5**	**SR-SS-019-000.5**	**SR-SS-020-000.5**	**SR-SS-020-000.5-D**	**SR-SS-021-000.5**	**SR-SS-022-000.5**	**SR-SS-023-000.5**
Sample Date		**10/22/2007**	**10/22/2007**	**10/22/2007**	**10/22/2007**	**10/22/2007**	**10/25/2007**	**10/24/2007**	**10/24/2007**	**10/24/07**	**10/25/2007**	**10/25/2007**	**10/25/2007**
PAH (µg/kg)													
Benzo(A)Anthracene	1,100	**1,200 J**	**1,600**	96	**1,500**	6.3 J	4.3 J	980	**9,800**	**9,600**	**2,600 J**	37	4.9 J
Benzo(A)Pyrene	110	**1,400**	**1,900**	**110**	**1,500**	8 J	5 J	**1,300**	**11,000**	**9,500**	**2,400**	35	4.6 J
Benzo(B)Fluoranthene	1,100	**1,900**	**3,000 J**	160 J	**1,200**	9.9 J	8.1 J	**2,200**	**9,000 J**	**15,000**	**2,600**	59	22 U
Benzo(K)Fluoranthene	11,000	920 J	1,400	74	1,600	5.4 J	23 U	330 J	8,100 J	6,400 J	1,400 J	18 J	22 U
Chrysene	110,000	1,200	1,700	93	1,800	6.6 J	23 U	1,100 J	11,000	11,000 J	2,200	42	22 U
Dibenzo(A,H)Anthracene	110	**570 J**	**740**	46	**350**	8.6 J	23 U	94	**3,500 J**	**1,400 J**	**1,100**	17 J	22 U
Indeno(1,2,3-CD)Pyrene	1,100	**1,300**	**1,400**	95	950 J	9 J	23 U	810 J	**7,300**	**5,400**	**1,900**	67	22 U
POINT RISK													
Benzo(A)Anthracene	1,100	1.1E-06	1.5E-06	8.7E-08	1.4E-06	5.7E-09	3.9E-09	8.9E-07	8.9E-06	8.7E-06	2.4E-06	3.4E-08	4.5E-09
Benzo(A)Pyrene	110	1.3E-05	1.7E-05	1.0E-06	1.4E-05	7.3E-08	4.5E-08	1.2E-05	1.0E-04	8.6E-05	2.2E-05	3.2E-07	4.2E-08
Benzo(B)Fluoranthene	1,100	1.7E-06	2.7E-06	1.5E-07	1.1E-06	9.0E-09	7.4E-09	2.0E-06	8.2E-06	1.4E-05	2.4E-06	5.4E-08	1.0E-08
Benzo(K)Fluoranthene	11,000	8.4E-08	1.3E-07	6.7E-09	1.5E-07	4.9E-10	1.0E-09	3.0E-08	7.4E-07	5.8E-07	1.3E-07	1.6E-09	1.0E-09
Chrysene	110,000	1.1E-08	1.5E-08	8.5E-10	1.6E-08	6.0E-11	1.0E-10	1.0E-08	1.0E-07	1.0E-07	2.0E-08	3.8E-10	1.0E-10
Dibenzo(A,H)Anthracene	110	5.2E-06	6.7E-06	4.2E-07	3.2E-06	7.8E-08	1.0E-07	8.5E-07	3.2E-05	1.3E-05	1.0E-05	1.5E-07	1.0E-07
Indeno(1,2,3-CD)Pyrene	1,100	1.2E-06	1.3E-06	8.6E-08	8.6E-07	8.2E-09	1.0E-08	7.4E-07	6.6E-06	4.9E-06	1.7E-06	6.1E-08	1.0E-08
TOTAL POINT RISK		**2.2E-05**	**3.0E-05**	**1.7E-06**	**2.0E-05**	**1.7E-07**	**1.7E-07**	**1.6E-05**	**1.6E-04**	**1.3E-04**	**3.8E-05**	**6.2E-07**	**1.7E-07**

Notes:

PAH Polycyclic aromatic hydrocarbon
µg/kg micrograms per kilogram
-D Duplicate sample
J Estimated value

1) If sample result was non-detect (U qualifier), 1/2 the detection limit was used for point risk calculation.
2) The seven PAHs in this table were determined to be risk drivers based on the risk ratio conducted during the Site Investigation (2008) and subsequent changes to the RSLs (through November 2018) due to updated toxicity values.
3) Total point risks calculated using the Residential Regional Screening Levels (RSLs) from November 2018 for each PAH identified as a risk driver.

Bolded and shaded values indicate exceedances of either the RSL or Total Point Risk of 1.0E-04

TABLE 4-4
PAH ANALYTICAL SUMMARY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

		SR-SS-024	SR-SS-025	SR-SS-026	SR-SS-027	SR-SS-028	SR-SS-029	SR-SS-030	SR-SS-031	SR-SS-032	SR-SS-033	SR-SS-034	SR-SS-035
Sample	**Residential RSL November 2018[1]**	SR-SS-024-000.5	SR-SS-025-000.5	SR-SS-026-000.5	SR-SS-027-000.5	SR-SS-028-000.5	SR-SS-029-000.5	SR-SS-030-000.5	SR-SS-031-000.5	SR-SS-032-000.5	SR-SS-033-000.5	SR-SS-034-000.5	SR-SS-035-000.5
Sample Date		10/25/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/25/2007	10/24/2007	10/25/2007
PAH (µg/kg)													
Benzo(A)Anthracene	1,100	4.7 J	**2,400**	**10,000**	950	18 J	**3,600**	5 J	440	360	**24,000 J**	**1,200 J**	60
Benzo(A)Pyrene	110	4.7 J	**3,500**	**12,000**	**810**	18 J	**3,500**	23 U	**290**	**330**	**22,000**	**1,200**	65 J
Benzo(B)Fluoranthene	1,100	23 U	**5,200**	**19,000**	**1,300**	20 J	**3,000 J**	6.8 J	460	330 J	**19,000**	**1,200**	120 J
Benzo(K)Fluoranthene	11,000	23 U	1,700 J	5,700 J	540 J	16 J	2,700 J	4.5 J	280 J	240 J	**14,000 J**	760 J	47 J
Chrysene	110,000	23 U	2,800 J	10,000 J	1,100 J	14 J	3,600 J	23 U	420 J	330 J	20,000 J	1,100 J	83 J
Dibenzo(A,H)Anthracene	110	23 U	**340**	**2,000 J**	**320**	8.5 J	**320 J**	23 U	**150**	**110**	**9,500**	**160 J**	13 J
Indeno(1,2,3-CD)Pyrene	1,100	23 U	**2,300 J**	**7,200 J**	490	16 J	**2,200**	23 U	270	200	**16,000**	800	44 J
POINT RISK													
Benzo(A)Anthracene	1,100	4.3E-09	2.2E-06	9.1E-06	8.6E-07	1.6E-08	3.3E-06	4.5E-09	4.0E-07	3.3E-07	2.2E-05	1.1E-06	5.5E-08
Benzo(A)Pyrene	110	4.3E-08	3.2E-05	1.1E-04	7.4E-06	1.6E-07	3.2E-05	1.0E-07	2.6E-06	3.0E-06	2.0E-04	1.1E-05	5.9E-07
Benzo(B)Fluoranthene	1,100	1.0E-08	4.7E-06	1.7E-05	1.2E-06	1.8E-08	2.7E-06	6.2E-09	4.2E-07	3.0E-07	1.7E-05	1.1E-06	1.1E-07
Benzo(K)Fluoranthene	11,000	1.0E-09	1.5E-07	5.2E-07	4.9E-08	1.5E-09	2.5E-07	4.1E-10	2.5E-08	2.2E-08	1.3E-06	6.9E-08	4.3E-09
Chrysene	110,000	1.0E-10	2.5E-08	9.1E-08	1.0E-08	1.3E-10	3.3E-08	1.0E-10	3.8E-09	3.0E-09	1.8E-07	1.0E-08	7.5E-10
Dibenzo(A,H)Anthracene	110	1.0E-07	3.1E-06	1.8E-05	2.9E-06	7.7E-08	2.9E-06	1.0E-07	1.4E-06	1.0E-06	8.6E-05	1.5E-06	1.2E-07
Indeno(1,2,3-CD)Pyrene	1,100	1.0E-08	2.1E-06	6.5E-06	4.5E-07	1.5E-08	2.0E-06	1.0E-08	2.5E-07	1.8E-07	1.5E-05	7.3E-07	4.0E-08
TOTAL POINT RISK		**1.7E-07**	**4.4E-05**	**1.6E-04**	**1.3E-05**	**2.9E-07**	**4.3E-05**	**2.3E-07**	**5.1E-06**	**4.8E-06**	**3.4E-04**	**1.5E-05**	**9.2E-07**

Notes:

PAH Polycyclic aromatic hydrocarbon
µg/kg micrograms per kilogram
-D Duplicate sample
J Estimated value

1) If sample result was non-detect (U qualifier), 1/2 the detection limit was used for point risk calculation.
2) The seven PAHs in this table were determined to be risk drivers based on the risk ratio conducted during the Site Investigation (2008) and subsequent changes to the RSLs (through November 2018) due to updated toxicity values.
3) Total point risks calculated using the Residential Regional Screening Levels (RSLs) from November 2018 for each PAH identified as a risk driver.

Bolded and shaded values indicate exceedances of either the RSL or Total Point Risk of 1.0E-04

TABLE 4-4
PAH ANALYTICAL SUMMARY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

		SR-SS-036	SR-SS-037	SR-SS-038	SR-SS-039	SR-SS-040	SR-SS-041		SR-SS-042	SR-SS-043	SR-SS-044	SR-SS-045	SR-SS-047
Sample	**Residential RSL November 2018[1]**	**SR-SS-036-000.5**	**SR-SS-037-000.5**	**SR-SS-038-000.5**	**SR-SS-039-000.5**	**SR-SS-040-000.5**	**SR-SS-041-000.5**	**SR-SS-041-000.5-D**	**SR-SS-042-000.5**	**SR-SS-043-000.5**	**SR-SS-044-000.5**	**SR-SS-045-000.5**	**SR-SS-047-000.5**
Sample Date		**10/18/2007**	**10/19/2007**	**10/19/2007**	**10/19/2007**	**11/6/2007**	**11/6/2007**	**11/6/2007**	**11/6/2007**	**11/6/2007**	**11/6/2007**	**11/6/2007**	**11/6/2007**
PAH (µg/kg)													
Benzo(A)Anthracene	1,100	9.4 J	10 J	13 J	14 J	4.2 J	8.7 J	14 J	3.5 J	5.2 J	66 J	9.6 J	46 J
Benzo(A)Pyrene	110	8.6 J	13 J	13 J	100 UJ	4.8 J	9.7 J	12 J	4.4 J	6.6 J	97	14 J	40
Benzo(B)Fluoranthene	1,100	9.9 J	17 J	22 J	100 UJ	7.4 J	13 J	19 J	24 U	10 J	130	14 J	49
Benzo(K)Fluoranthene	11,000	6 J	8.3 J	11 J	100 UJ	4.2 J	7.5 J	11 J	24 U	5.4 J	69 J	9.6 J	27 J
Chrysene	110,000	8.8 J	11 J	14 J	18 J	4.5 J	9.3 J	14 J	4.3 J	6 J	70	11 J	39
Dibenzo(A,H)Anthracene	110	21 U	23 U	9.4 J	100 UJ	24 U	24 U	24 U	24 U	23 U	54 J	25 U	19 J
Indeno(1,2,3-CD)Pyrene	1,100	6.9 J	11 J	11 J	100 UJ	24 U	8.6 J	12 J	24 U	6 J	110	12 J	33
POINT RISK													
Benzo(A)Anthracene	1,100	8.5E-09	9.1E-09	1.2E-08	1.3E-08	3.8E-09	7.9E-09	1.3E-08	3.2E-09	4.7E-09	6.0E-08	8.7E-09	4.2E-08
Benzo(A)Pyrene	110	7.8E-08	1.2E-07	1.2E-07	4.5E-07	4.4E-08	8.8E-08	1.1E-07	4.0E-08	6.0E-08	8.8E-07	1.3E-07	3.6E-07
Benzo(B)Fluoranthene	1,100	9.0E-09	1.5E-08	2.0E-08	4.5E-08	6.7E-09	1.2E-08	1.7E-08	1.1E-08	9.1E-09	1.2E-07	1.3E-08	4.5E-08
Benzo(K)Fluoranthene	11,000	5.5E-10	7.5E-10	1.0E-09	4.5E-09	3.8E-10	6.8E-10	1.0E-09	1.1E-09	4.9E-10	6.3E-09	8.7E-10	2.5E-09
Chrysene	110,000	8.0E-11	1.0E-10	1.3E-10	1.6E-10	4.1E-11	8.5E-11	1.3E-10	3.9E-11	5.5E-11	6.4E-10	1.0E-10	3.5E-10
Dibenzo(A,H)Anthracene	110	9.5E-08	1.0E-07	8.5E-08	4.5E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.0E-07	4.9E-07	1.1E-07	1.7E-07
Indeno(1,2,3-CD)Pyrene	1,100	6.3E-09	1.0E-08	1.0E-08	4.5E-08	1.1E-08	7.8E-09	1.1E-08	1.1E-08	5.5E-09	1.0E-07	1.1E-08	3.0E-08
TOTAL POINT RISK		**2.0E-07**	**2.6E-07**	**2.5E-07**	**1.0E-06**	**1.7E-07**	**2.3E-07**	**2.6E-07**	**1.8E-07**	**1.8E-07**	**1.7E-06**	**2.7E-07**	**6.6E-07**

Notes:
PAH Polycyclic aromatic hydrocarbon
µg/kg micrograms per kilogram
-D Duplicate sample
J Estimated value
1) If sample result was non-detect (U qualifier), 1/2 the detection limit was used for point risk calculation.
2) The seven PAHs in this table were determined to be risk drivers based on the risk ratio conducted during the Site Investigation (2008) and subsequent changes to the RSLs (through November 2018) due to updated toxicity values.
3) Total point risks calculated using the Residential Regional Screening Levels (RSLs) from November 2018 for each PAH identified as a risk driver.

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TABLE 4-4
PAH ANALYTICAL SUMMARY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

		SR-SS-049	SR-SS-050	SR-SS-051	SR-SS-052	SR-SS-053	SR-SS-054	SR-SS-055	SR-SS-056
Sample	**Residential RSL November 2018[1]**	**SR-SS-049-000.5**	**SR-SS-050-000.5**	**SR-SS-051-000.5**	**SR-SS-052-000.5**	**SR-SS-053-000.5**	**SR-SS-054-000.5**	**SR-SS-055-000.5**	**SR-SS-056-000.5**
Sample Date		**11/6/2007**	**11/7/2007**	**11/7/2007**	**11/7/2007**	**11/7/2007**	**11/7/2007**	**11/7/2007**	**11/7/2007**
PAH (µg/kg)									
Benzo(A)Anthracene	1,100	13 J	35	310 J	14 J	54	540	4.8 J	3.1 J
Benzo(A)Pyrene	110	13 J	31	**240**	13 J	46	**450**	6.1 J	3.7 J
Benzo(B)Fluoranthene	1,100	14 J	28 J	230 J	15 J	45 J	410 J	5.8 J	4.9 J
Benzo(K)Fluoranthene	11,000	9.3 J	20 J	160 J	9.6 J	33	300 J	5.1 J	3.6 J
Chrysene	110,000	12 J	24 J	240	9.5 J	41	430	23 U	24 U
Dibenzo(A,H)Anthracene	110	25 U	17 J	98	8.4 J	20 J	**180**	23 U	24 U
Indeno(1,2,3-CD)Pyrene	1,100	9.6 J	28	170	15 J	37	310	8.3 J	24 U
POINT RISK									
Benzo(A)Anthracene	1,100	1.2E-08	3.2E-08	2.8E-07	1.3E-08	4.9E-08	4.9E-07	4.4E-09	2.8E-09
Benzo(A)Pyrene	110	1.2E-07	2.8E-07	2.2E-06	1.2E-07	4.2E-07	4.1E-06	5.5E-08	3.4E-08
Benzo(B)Fluoranthene	1,100	1.3E-08	2.5E-08	2.1E-07	1.4E-08	4.1E-08	3.7E-07	5.3E-09	4.5E-09
Benzo(K)Fluoranthene	11,000	8.5E-10	1.8E-09	1.5E-08	8.7E-10	3.0E-09	2.7E-08	4.6E-10	3.3E-10
Chrysene	110,000	1.1E-10	2.2E-10	2.2E-09	8.6E-11	3.7E-10	3.9E-09	1.0E-10	1.1E-10
Dibenzo(A,H)Anthracene	110	1.1E-07	1.5E-07	8.9E-07	7.6E-08	1.8E-07	1.6E-06	1.0E-07	1.1E-07
Indeno(1,2,3-CD)Pyrene	1,100	8.7E-09	2.5E-08	1.5E-07	1.4E-08	3.4E-08	2.8E-07	7.5E-09	1.1E-08
TOTAL POINT RISK		**2.7E-07**	**5.2E-07**	**3.7E-06**	**2.4E-07**	**7.3E-07**	**6.9E-06**	**1.8E-07**	**1.6E-07**

Notes:

PAH Polycyclic aromatic hydrocarbon
µg/kg micrograms per kilogram
-D Duplicate sample
J Estimated value

1) If sample result was non-detect (U qualifier), 1/2 the detection limit was used for point risk calculation.
2) The seven PAHs in this table were determined to be risk drivers based on the risk ratio conducted during the Site Investigation (2008) and subsequent changes to the RSLs (through November 2018) due to updated toxicity values.
3) Total point risks calculated using the Residential Regional Screening Levels (RSLs) from November 2018 for each PAH identified as a risk driver.

Bolded and shaded values indicate exceedances of either the RSL or Total Point Risk of 1.0E-04

				#10 SIEVE						#14 SIEVE				#20 SIEVE				#35 SIEVE				
Sample	Method	Area (Feet^2)	Volume (Feet^3)	Lead Shot	Grit Sized Particles	Clay Pigeon Frags	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Adjusted(1) Clay Pigeon Frags	Lead Shot	Grit Sized Particles	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Lead Shot	Grit Sized Particles	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Lead Shot	Grit Sized Particles	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Notes
SOUTHERN RANGE AREA																						
SR-SS-216-0006	1ft x 1ft	1	0.5	294	153	5	294	153	5	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-216-0612	1ft x 1ft	1	0.5	72	46	3	72	46	3	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-216-1224	3in HA	0.05	0.05	5	23	0	25	115	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-217-0006	1ft x 1ft	1	0.5	419	151	0	419	151	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-217-0612	1ft x 1ft	1	0.5	92	167	0	92	167	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-217-1224	3in HA	0.05	0.05	0	11	0	0	55	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-218-0006	1ft x 1ft	1	0.5	218	178	0	218	178	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-218-0612	1ft x 1ft	1	0.5	138	39	0	138	39	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-218-1224	3in HA	0.05	0.05	6	7	0	30	35	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-219-0006	1ft x 1ft	1	0.5	533	119	0	533	119	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-219-0612	1ft x 1ft	1	0.5	46	155	0	46	155	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-219-1224	3in HA	0.05	0.05	1	35	0	5	175	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-220-0006	1ft x 1ft	1	0.5	66	75	0	66	75	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-220-0612	1ft x 1ft	1	0.5	193	58	0	193	58	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-220-1224	3in HA	0.05	0.05	9	18	0	45	90	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-221-0006	1ft x 1ft	1	0.5	148	144	12	148	144	12	3	1,118	3	1,118	0	33,575	0	33,575	0	>100,000	0	>100,000	Field sieved #35 and laboratory sieved #20
SR-SS-221-0612	1ft x 1ft	1	0.5	53	99	0	53	99	0	1	1,438	1	1,438	0	51,840	0	51,840	0	>100,000	0	>100,000	Field sieved #35 and laboratory sieved #20
SR-SB-221-1224	3in HA	0.05	0.05	5	18	0	25	90	0	0	55	0	275	0	1,825	0	9,125	0	>100,000	0	>100,000	Field sieved #35 and laboratory sieved #20
SR-SS-222-0006	1ft x 1ft	1	0.5	15	~1,000	4	15	~1,000	4	--	--	--	--	--	--	--	--	--	--	--	--	Non-lead particles very high, estimated #10 sieve value
SR-SS-222-0612	1ft x 1ft	1	0.5	2	~1,000	0	2	~1,000	0	--	--	--	--	--	--	--	--	--	--	--	--	Non-lead particles very high, estimated #10 sieve value
SR-SB-222-1224	3in HA	0.05	0.05	0	~200	0	0	~1,000	0	--	--	--	--	--	--	--	--	--	--	--	--	Non-lead particles very high, estimated #10 sieve value
SR-SS-223-0006	1ft x 1ft	1	0.5	0	~750	50	0	~750	50	--	--	--	--	--	--	--	--	--	--	--	--	Non-lead particles very high, estimated #10 sieve value
SR-SS-223-0612	1ft x 1ft	1	0.5	5	~700	40	5	~700	40	--	--	--	--	--	--	--	--	--	--	--	--	Non-lead particles very high, estimated #10 sieve value
SR-SB-223-1224	3in HA	0.05	0.05	0	50	3	0	250	15	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-224-0006	1ft x 1ft	1	0.5	6	~1000	2	6	~1000	2	--	--	--	--	--	--	--	--	--	--	--	--	Non-lead particles very high, estimated #10 sieve value
SR-SS-224-0612	1ft x 1ft	1	0.5	1	~750	0	1	~750	0	--	--	--	--	--	--	--	--	--	--	--	--	Non-lead particles very high, estimated #10 sieve value
SR-SB-224-1224	3in HA	0.05	0.05	0	~100	0	0	~500	0	--	--	--	--	--	--	--	--	--	--	--	--	Non-lead particles very high, estimated #10 sieve value
SR-SS-225-0006	1ft x 1ft	1	0.5	0	~300	0	0	~300	0	0	5,657	0	5,657	0	86,900	0	86,900	0	>100,000	0	>100,000	Non-lead particles very high, estimated #10 sieve value. Field sieved #35 and laboratory sieved #20
SR-SS-225-0612	1ft x 1ft	1	0.5	8	~300	3	8	~300	3	0	3,408	0	3,408	0	56,686	0	56,686	0	>100,000	0	>100,000	Non-lead particles very high, estimated #10 sieve value. Field sieved #35 and laboratory sieved #20
SR-SB-225-1224	3in HA	0.05	0.05	0	75	0	0	375	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-226-0006	1ft x 1ft	1	0.5	1	~200	0	1	~200	0	--	--	--	--	--	--	--	--	--	--	--	--	Non-lead particles very high, estimated #10 sieve value
SR-SS-226-0612	1ft x 1ft	1	0.5	7	~300	0	7	~300	0	--	--	--	--	--	--	--	--	--	--	--	--	Non-lead particles very high, estimated #10 sieve value
SR-SB-226-1224	3in HA	0.05	0.05	0	~100	0	0	~500	0	--	--	--	--	--	--	--	--	--	--	--	--	Non-lead particles very high, estimated #10 sieve value
SR-SS-227-0006	7in x 7in	0.34	0.17	102	92	6	300	270	18	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-227-0612	7in x 7in	0.34	0.17	8	66	0	24	194	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-227-1218	3in HA	0.05	0.025	0	0	0	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-227-1824	3in HA	0.05	0.025	0	0	0	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-228-0006	7in x 7in	0.34	0.17	20	24	6	59	71	18	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-228-0612	7in x 7in	0.34	0.17	0	18	0	0	53	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-229-0006	7in x 7in	0.34	0.17	7	140	6	21	412	18	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-229-0612	7in x 7in	0.34	0.17	0	35	0	0	103	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-230-0006	7in x 7in	0.34	0.17	72	51	255	212	150	750	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-230-0612	7in x 7in	0.34	0.17	17	30	10	50	88	29	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-230-1218	3in HA	0.05	0.025	0	5	0	0	50	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-230-1824	3in HA	0.05	0.025	0	2	0	0	20	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-231-0006	7in x 7in	0.34	0.17	93	31	0	273	91	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-231-0612	7in x 7in	0.34	0.17	2	7	0	6	21	0	--	--	--	--	--	--	--	--	--	--	--	--	

TABLE 4-5
LEAD SHOT AND NON-LEAD GRIT SIZED PARTICLE COUNTS
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

				#10 SIEVE						#14 SIEVE				#20 SIEVE				#35 SIEVE				
Sample	Method	Area (Feet²)	Volume (Feet³)	Lead Shot	Grit Sized Particles	Clay Pigeon Frags	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Adjusted(1) Clay Pigeon Frags	Lead Shot	Grit Sized Particles	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Lead Shot	Grit Sized Particles	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Lead Shot	Grit Sized Particles	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Notes
SOUTHERN RANGE AREA (continued)																						
SR-SB-231-1218	3in HA	0.05	0.025	0	3	0	0	30	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-231-1824	3in HA	0.05	0.025	0	2	0	0	20	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-232-0006	7in x 7in	0.34	0.17	15	400	0	44	1,176	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-232-0612	7in x 7in	0.34	0.17	13	155	10	38	456	29	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-232-1218	3in HA	0.05	0.025	0	10	3	0	100	30	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-232-1824	3in HA	0.05	0.025	0	7	0	0	70	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-233-0006	7in x 7in	0.34	0.17	74	38	0	218	112	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-233-0612	7in x 7in	0.34	0.17	6	19	0	18	56	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-233-1218	3in HA	0.05	0.025	0	5	0	0	50	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-233-1824	3in HA	0.05	0.025	0	3	0	0	30	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-234-0006	7in x 7in	0.34	0.17	154	92	0	453	270	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-234-0612	7in x 7in	0.34	0.17	11	30	0	32	88	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-234-1218	3in HA	0.05	0.025	0	1	0	0	10	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-234-1824	3in HA	0.05	0.025	0	0	0	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-235-0006	7in x 7in	0.34	0.17	329	145	3	967	426	9	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-235-0612	7in x 7in	0.34	0.17	18	88	0	53	259	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-235-1218	3in HA	0.05	0.025	0	6	0	0	60	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-235-1824	3in HA	0.05	0.025	0	6	0	0	60	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-236-0006	7in x 7in	0.34	0.17	115	112	3	338	329	9	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-236-0612	7in x 7in	0.34	0.17	9	50	0	26	147	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-236-1218	3in HA	0.05	0.025	0	19	0	0	190	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-236-1824	3in HA	0.05	0.025	1	6	0	10	60	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-237-0006	7in x 7in	0.34	0.17	82	243	0	241	714	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-237-0612	7in x 7in	0.34	0.17	23	125	0	68	368	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-237-1218	3in HA	0.05	0.025	0	10	0	0	100	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-237-1824	3in HA	0.05	0.025	0	7	0	0	70	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-238-0006	7in x 7in	0.34	0.17	18	250	0	53	735	0	--	--	--	--	--	--	--	--	--	--	--	--	March 2018
SR-SS-238-0006	7in x 7in	0.34	0.17	11	30	2	32	88	6	1	408	3	1,200	0	9,072	0	26,672	--	--	--	--	December 2018
SR-SS-238-0612	7in x 7in	0.34	0.17	0	27	0	0	79	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-239-0006	7in x 7in	0.34	0.17	28	300	0	82	882	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-239-0612	7in x 7in	0.34	0.17	0	32	0	0	94	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-240-0006	7in x 7in	0.34	0.17	34	155	0	100	456	0	--	--	--	--	--	--	--	--	--	--	--	--	March 2018
SR-SS-240-0006	7in x 7in	0.34	0.17	81	49	0	238	144	0	1	678	3	1,993	0	10,136	0	29,800	--	--	--	--	December 2018
SR-SS-240-0612	7in x 7in	0.34	0.17	1	103	0	3	303	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-308-0006	7in x 7in	0.34	0.17	0	>1,000	0	0	>3,000	0	--	--	--	--	--	--	--	--	--	--	--	--	Non-lead particles very high, estimated #10 sieve value
SR-SS-308-0612	7in x 7in	0.34	0.17	4	577	0	12	1,696	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-309-0006	7in x 7in	0.34	0.17	7	17	6	21	50	18	14	660	41	1,940	0	11,294	0	33,204	--	--	--	--	
SR-SS-309-0612	7in x 7in	0.34	0.17	0	21	0	0	62	0	2	474	6	1,394	0	10,725	0	31,532	--	--	--	--	
SR-SS-310-0006	7in x 7in	0.34	0.17	27	20	17	79	59	50	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-310-0612	7in x 7in	0.34	0.17	16	20	17	47	59	50	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-311-0006	7in x 7in	0.34	0.17	10	30	78	29	88	229	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-311-0612	7in x 7in	0.34	0.17	13	20	46	38	59	135	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-312-0006	7in x 7in	0.34	0.17	20	83	29	59	244	85	0	725	0	2,132	0	16,855	0	49,554	--	--	--	--	
SR-SS-312-0612	7in x 7in	0.34	0.17	5	80	13	15	235	38	0	712	0	2,093	0	18,960	0	55,742	--	--	--	--	
SR-SS-313-0006	7in x 7in	0.34	0.17	0	11	0	0	32	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-313-0612	7in x 7in	0.34	0.17	5	43	0	15	126	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-314-0006	7in x 7in	0.34	0.17	0	392	0	0	1,152	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-314-0612	7in x 7in	0.34	0.17	2	114	0	6	335	0	--	--	--	--	--	--	--	--	--	--	--	--	

TABLE 4-5
LEAD SHOT AND NON-LEAD GRIT SIZED PARTICLE COUNTS
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

				#10 SIEVE						#14 SIEVE				#20 SIEVE				#35 SIEVE				
Sample	Method	Area ($Feet^2$)	Volume ($Feet^3$)	Lead Shot	Grit Sized Particles	Clay Pigeon Frags	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Adjusted(1) Clay Pigeon Frags	Lead Shot	Grit Sized Particles	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Lead Shot	Grit Sized Particles	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Lead Shot	Grit Sized Particles	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Notes
SOUTHERN RANGE AREA (continued)																						
SR-SB-315-0006	7in x 7in	0.34	0.17	10	22	0	29	65	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-315-0612	7in x 7in	0.34	0.17	10	39	0	29	115	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-316-0006	7in x 7in	0.34	0.17	6	45	0	18	132	0	2	472	6	1,388	0	11,018	0	32,393	--	--	--	--	
SR-SS-316-0612	7in x 7in	0.34	0.17	4	28	0	12	82	0	0	715	0	2,102	0	14,528	0	42,712	--	--	--	--	
SR-SS-317-0006	7in x 7in	0.34	0.17	4	18	0	12	53	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-317-0612	7in x 7in	0.34	0.17	0	21	0	0	62	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-328-0006	7in x 7in	0.34	0.17	1	22	2	3	65	6	0	203	0	597	0	3,626	0	10,660	--	--	--	--	
SR-SS-328-0612	7in x 7in	0.34	0.17	0	32	1	0	94	3	0	209	0	614	0	3,874	0	11,390	--	--	--	--	
SR-SS-329-0006	7in x 7in	0.34	0.17	6	12	9	18	35	26	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-329-0612	7in x 7in	0.34	0.17	1	21	4	3	62	12	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-330-0006	7in x 7in	0.34	0.17	4	29	0	12	85	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-330-0612	7in x 7in	0.34	0.17	0	21	0	0	62	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-331-0006	7in x 7in	0.34	0.17	26	234	0	76	688	0	1	1,382	3	4,063	0	21,928	0	64,468	--	--	--	--	
SR-SS-331-0612	7in x 7in	0.34	0.17	13	205	0	38	603	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-401-0006	7in x 7in	0.34	0.17	16	445	0	47	1,308	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-402-0006	7in x 7in	0.34	0.17	45	609	0	132	1,790	0	0	367	0	1,079	--	--	--	--	--	--	--	--	
SR-SS-402-0612	7in x 7in	0.34	0.17	6	781	0	18	2,296	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-403-0006	7in x 7in	0.34	0.17	47	103	0	138	303	0	0	324	0	953	--	--	--	--	--	--	--	--	
SR-SS-403-0612	7in x 7in	0.34	0.17	16	154	0	47	453	0	0	347	0	1,020	--	--	--	--	--	--	--	--	
SR-SS-404-0006	7in x 7in	0.34	0.17	3	418	0	9	1,229	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-405-0006	7in x 7in	0.34	0.17	1	14	0	3	41	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-406-0006	7in x 7in	0.34	0.17	0	111	0	0	326	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-422-0006	7in x 7in	0.34	0.17	52	529	0	153	1,555	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-422-0612	7in x 7in	0.34	0.17	25	628	0	74	1,846	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-423-0006	7in x 7in	0.34	0.17	15	749	0	44	2,202	0	--	--	--	--	--	--	--	--	--	--	--	--	
HIGH TOWER RANGE AREA																						
SR-SS-241-0006	7in x 7in	0.34	0.17	5	25	0	15	74	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-241-0006	7in x 7in	0.34	0.17	1	15	0	3	44	0	0	296	0	870	0	6,269	0	18,431	--	--	--	--	
SR-SS-241-0612	7in x 7in	0.34	0.17	0	21	0	0	62	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-246-0006	7in x 7in	0.34	0.17	2	88	0	6	259	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-246-0612	7in x 7in	0.34	0.17	0	24	0	0	71	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-246-1218	3in HA	0.05	0.025	0	4	0	0	40	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-246-1824	3in HA	0.05	0.025	0	6	0	0	60	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-251-0006	7in x 7in	0.34	0.17	0	250	0	0	735	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-251-0612	7in x 7in	0.34	0.17	0	50	0	0	147	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-252-0006	7in x 7in	0.34	0.17	27	13	0	79	38	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-252-0612	7in x 7in	0.34	0.17	11	13	0	32	38	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-253-0006	7in x 7in	0.34	0.17	29	106	13	85	312	38	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-253-0612	7in x 7in	0.34	0.17	0	4	0	0	12	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-253-1218	3in HA	0.05	0.025	0	28	0	0	280	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-253-1824	3in HA	0.05	0.025	0	23	0	0	230	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-254-0006	7in x 7in	0.34	0.17	7	4	2	21	12	6	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-254-0612	7in x 7in	0.34	0.17	6	5	3	18	15	9	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-255-0006	7in x 7in	0.34	0.17	64	28	0	188	82	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-255-0612	7in x 7in	0.34	0.17	4	32	0	12	94	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-256-0006	7in x 7in	0.34	0.17	122	109	0	359	320	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-256-0612	7in x 7in	0.34	0.17	0	63	0	0	185	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-256-1218	3in HA	0.05	0.025	0	9	0	0	90	0	--	--	--	--	--	--	--	--	--	--	--	--	

TABLE 4-5
LEAD SHOT AND NON-LEAD GRIT SIZED PARTICLE COUNTS
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

				#10 SIEVE						#14 SIEVE				#20 SIEVE				#35 SIEVE				
Sample	Method	Area (Feet²)	Volume (Feet³)	Lead Shot	Grit Sized Particles	Clay Pigeon Frags	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Adjusted(1) Clay Pigeon Frags	Lead Shot	Grit Sized Particles	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Lead Shot	Grit Sized Particles	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Lead Shot	Grit Sized Particles	Adjusted(1) Lead Shot	Adjusted(1) Grit Sized Particles	Notes
HIGH TOWER RANGE AREA (continued)																						
SR-SB-256-1824	3in HA	0.05	0.025	0	6	0	0	60	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-256N-0006	7in x 7in	0.34	0.17	56	68	0	165	200	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-256N-0612	7in x 7in	0.34	0.17	4	49	0	12	144	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-256E-0006	7in x 7in	0.34	0.17	54	313	0	159	920	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-256E-0612	7in x 7in	0.34	0.17	5	246	0	15	723	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-318-0006	7in x 7in	0.34	0.17	30	272	0	88	800	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-319-0006	7in x 7in	0.34	0.17	4	52	0	12	153	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-320-0006	7in x 7in	0.34	0.17	20	97	0	59	285	0	0	755	0	2,220	0	11,917	0	35,036	--	--	--	--	
SR-SB-321-0006	7in x 7in	0.34	0.17	24	175	0	71	515	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-322-0006	7in x 7in	0.34	0.17	15	90	0	44	265	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SB-323-0006	7in x 7in	0.34	0.17	32	59	0	94	173	0	0	790	0	2,323	0	14,057	0	41,328	--	--	--	--	
SR-SS-324-0006	7in x 7in	0.34	0.17	63	78	0	185	229	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-332-0006	7in x 7in	0.34	0.17	14	233	0	41	685	0	1	1,283	3	3,772	0	20,226	0	59,464	--	--	--	--	
SR-SS-333-0006	7in x 7in	0.34	0.17	3	6	150	9	18	441	0	1,371	0	4,031	0	23,786	0	69,931	--	--	--	--	
SR-SS-334-0006	7in x 7in	0.34	0.17	45	94	0	132	276	0	0	843	0	2,478	0	17,254	0	50,727	--	--	--	--	
SR-SS-407-0006	7in x 7in	0.34	0.17	32	62	12	94	182	35	0	241	0	709	--	--	--	--	--	--	--	--	
SR-SS-407-0612	7in x 7in	0.34	0.17	45	86	11	132	253	32	1	285	3	838	--	--	--	--	--	--	--	--	
SR-SS-408-0006	7in x 7in	0.34	0.17	35	115	0	103	338	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-408-0612	7in x 7in	0.34	0.17	11	26	0	32	76	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-409-0006	7in x 7in	0.34	0.17	73	1633	0	215	4,801	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-409-0612	7in x 7in	0.34	0.17	13	922	0	38	2,711	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-410-0006	7in x 7in	0.34	0.17	61	252	0	179	741	0	0	1,071	0	3,149	--	--	--	--	--	--	--	--	
SR-SS-410-0612	7in x 7in	0.34	0.17	11	618	0	32	1,817	0	0	1,934	0	5,686	--	--	--	--	--	--	--	--	
SR-SS-411-0006	7in x 7in	0.34	0.17	11	35	0	32	103	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-412-0006	7in x 7in	0.34	0.17	6	905	0	18	2,661	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-413-0006	7in x 7in	0.34	0.17	12	66	0	35	194	0	0	262	0	770	--	--	--	--	--	--	--	--	
SR-SS-414-0006	7in x 7in	0.34	0.17	10	65	0	29	191	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-415-0006	7in x 7in	0.34	0.17	5	678	0	15	1,993	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-416-0006	7in x 7in	0.34	0.17	49	260	0	144	764	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-416-0612	7in x 7in	0.34	0.17	14	184	0	41	541	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-417-0006	7in x 7in	0.34	0.17	55	172	0	162	506	0	0	633	0	1,861	--	--	--	--	--	--	--	--	
SR-SS-417-0612	7in x 7in	0.34	0.17	37	522	0	109	1,535	0	0	1,161	0	3,413	--	--	--	--	--	--	--	--	
SR-SS-418-0006	7in x 7in	0.34	0.17	13	162	0	38	476	0	0	313	0	920	--	--	--	--	--	--	--	--	
SR-SS-419-0006	7in x 7in	0.34	0.17	70	28	0	206	82	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-420-0006	7in x 7in	0.34	0.17	3	451	0	9	1,326	0	--	--	--	--	--	--	--	--	--	--	--	--	
SR-SS-421-0006	7in x 7in	0.34	0.17	49	68	0	144	200	0	--	--	--	--	--	--	--	--	--	--	--	--	

Notes:
(1) Adjusted to a 1-foot by 1-foot by 6inch volume (0.5 feet³)
1ft x 1ft - 1 foot by 1 foot square
3in HA - 3-inch diameter hand auger
7in x 7in - 7-inch by 7 inch square

TABLE 4-6
LABORATORY GRAIN SIZE AND SIEVE SUMMARY
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

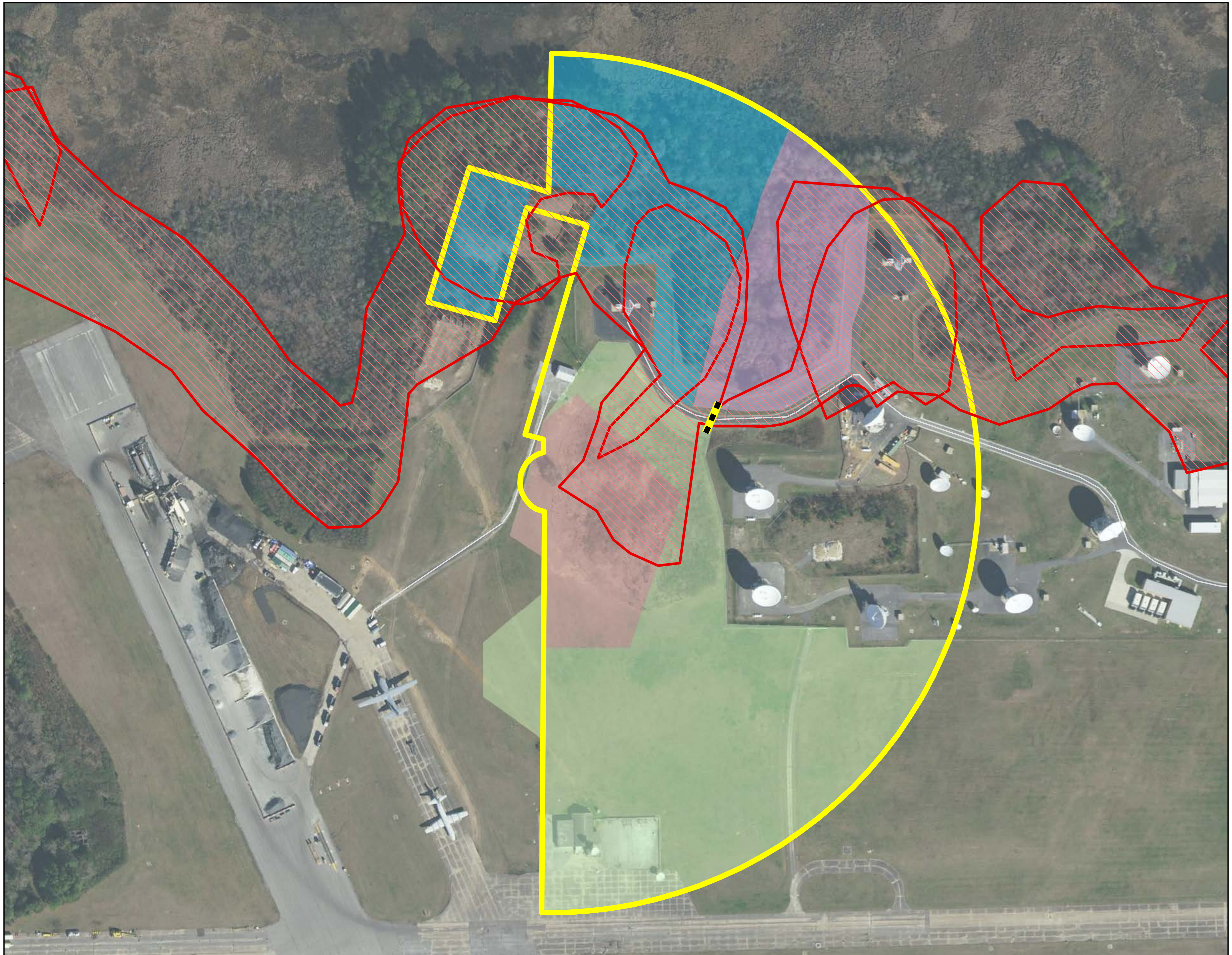
	SR-SS-221			SR-SS-225			SR-SS-227		SR-SS-246		
SAMPLE	**SR-SS-221-0006**	**SR-SS-221-0612**	**SR-SB-221-1224**	**SR-SS-225-0006**	**SR-SS-225-0612**	**SR-SB-225-1224**	**SR-SS-227-0006**	**SR-SS-227-0612**	**SR-SS-246-0006**	**SR-SS-246-0612**	**SR-SB-246-1224**
SAMPLE DATE	**3/21/2018**	**3/21/2018**	**3/22/2018**	**3/20/2018**	**3/20/2018**	**3/21/2018**	**3/26/2018**	**3/26/2018**	**3/23/2018**	**3/23/2018**	**3/23/2018**
Lead (mg/kg)	245	63.9	18.8	149	153	7.34	158	27.8	92.1 B	8.9 B	10.4 B
Lead Sieve 20 (mg/kg)	153	728	33.9	19.5	139	--	--	--	--	--	--
Lead Sieve Pan (mg/kg)	138	45.8	43.9	12	55.1	--	--	--	--	--	--
Lead Pellet Count	0	0	0	0	0	--	--	--	--	--	--
Pellet Count Percent	0	0	0	0	0	--	--	--	--	--	--
Percent Gravel	--	--	--	0	0	0	0.38	0	0	0.3	0.07
Percent Course Sand	--	--	--	0.82	0.6	0.67	9.05	3.45	2.17	5.01	8.93
Percent Medium Sand	--	--	--	18.83	20.01	21.89	39.65	35.29	26.64	31.67	37.58
Percent Fine Sand	--	--	--	67.94	70.79	65.33	35.16	43.64	38.46	32.33	26.12
Percent Fines	--	--	--	12.42	8.6	12.11	15.77	17.62	32.73	30.69	27.3
Sieve 3" (% passing)	--	--	--	100	100	100	100	100	100	100	100
Sieve 2" (% passing)	--	--	--	100	100	100	100	100	100	100	100
Sieve 1-1/2" (% passing)	--	--	--	100	100	100	100	100	100	100	100
Sieve 1" (% passing)	--	--	--	100	100	100	100	100	100	100	100
Sieve 3/4" (% passing)	--	--	--	100	100	100	100	100	100	100	100
Sieve 1/4" (% passing)	--	--	--	100	100	100	100	100	100	100	100
Sieve No. 004 or 4.74 mm (% passing)	--	--	--	100	100	100	99.62	100	100	99.7	99.93
Sieve No. 010 or 2 mm (% passing)	--	--	--	99.18	99.4	99.33	90.57	96.55	97.83	94.69	91
Sieve No. 020 or 0.85 mm (% passing)	--	--	--	96.18	95.94	95.12	68.44	79.9	86.55	78.22	68.75
Sieve No. 040 or 0.42 mm (% passing)	--	--	--	80.36	79.39	77.44	50.92	61.27	71.19	63.02	53.42
Sieve No. 060 or 0.25 mm (% passing)	--	--	--	51.98	42.83	47.64	35.01	42.89	55.97	50.42	42.93
Sieve No. 080 or 0.177 mm (% passing)	--	--	--	30.15	22.07	26.26	24.56	30.82	46.45	42.39	37.13
Sieve No. 100 or 0.149 mm (% passing)	--	--	--	20.06	12.82	17.33	21.86	24.12	40.95	37.69	33.78
Sieve No. 200 or 0.074 mm (% passing)	--	--	--	12.42	8.6	12.11	15.77	17.62	32.73	30.69	27.3
TOTAL SOLIDS	--	--	--	**85**	**87**	**90**	**85**	**87**	**49**	**82**	**82**

Notes:
mg/kg - miligrams per kilogram

LIST OF SAMPLES
USED FOR EVALUATION OF
EXPOSURE AREAS IN THE RI REPORT

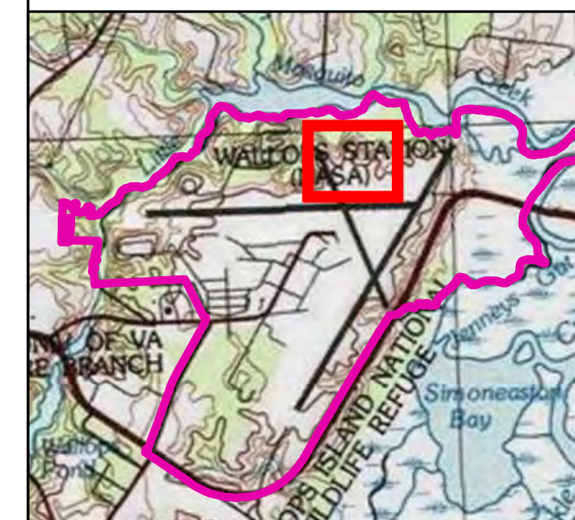
Northern Range Area			High Tower Area	
Surface Soils	Low-Lying Soils Evaluated as Surface Sediment	Subsurface Soils	Surface Soils	Subsurface Soils
SR-SS-006-000.5-20071019	SR-SS-006-000.5-20071019	SR-SB-201-1224	SR-SS-005-000.5-20071018	SR-SB-246-1224-20180323
SR-SS-012-000.5-20071018	SR-SS-012-000.5-20071018	SR-SB-202-1224	SR-SS-241-0006	SR-SB-246-1224-20180323-AVG
SR-SS-037-000.5-20071019	SR-SS-037-000.5-20071019	SR-SB-203-1224	SR-SS-242-0006	SR-SB-246-1224-20180323-D
SR-SS-038-000.5-20071019	SR-SS-038-000.5-20071019	SR-SS-201-0612	SR-SS-242-0006-AVG	SR-SB-250-1224
SR-SS-039-000.5-20071019	SR-SS-039-000.5-20071019	SR-SS-202-0612	SR-SS-242-0006-D	SR-SB-253-1224
SR-SS-100-000.5	SR-SS-100-000.5	SR-SS-203-0612	SR-SS-243-0006	SR-SB-256-1224
SR-SS-100-000.5-AVG	SR-SS-100-000.5-AVG	SR-SS-204-0612	SR-SS-244-0006	SR-SS-241-0612
SR-SS-100-000.5-D	SR-SS-100-000.5-D	SR-SS-205-0612	SR-SS-245-0006	SR-SS-242-0612
SR-SS-102-000.5	SR-SS-102-000.5	SR-SS-206-0612	SR-SS-246-0006-20180323	SR-SS-243-0612
SR-SS-103-000.5	SR-SS-103-000.5	SR-SS-207-0612	SR-SS-247-0006	SR-SS-243-1224
SR-SS-104-000.5	SR-SS-104-000.5	SR-SS-208-0612	SR-SS-248-0006	SR-SS-244-0612
SR-SS-105-000.5	SR-SS-105-000.5	SR-SS-209-0612	SR-SS-249-0006	SR-SS-245-0612
SR-SS-106-000.5	SR-SS-106-000.5	SR-SS-210-0612	SR-SS-250-0006	SR-SS-246-0612-20180323
SR-SS-107-000.5	SR-SS-107-000.5	SR-SS-211-0612	SR-SS-251-0006	SR-SS-247-0612
SR-SS-108-000.5	SR-SS-108-000.5	SR-SS-212-0612	SR-SS-252-0006	SR-SS-248-0612
SR-SS-201-0006	SR-SS-201-0006	SR-SS-213-0612	SR-SS-253-0006	SR-SS-249-0612
SR-SS-202-0006	SR-SS-202-0006	SR-SS-214-0612	SR-SS-253-0006-AVG	SR-SS-250-0612
SR-SS-203-0006	SR-SS-203-0006	SR-SS-215-0612	SR-SS-253-0006-D	SR-SS-251-0612
SR-SS-203-0006-AVG	SR-SS-203-0006-AVG	SR-SS-301-0612	SR-SS-254-0006	SR-SS-252-0612
SR-SS-203-0006-D	SR-SS-203-0006-D	SR-SS-302-0612	SR-SS-255-0006	SR-SS-253-0612
SR-SS-204-0006	SR-SS-204-0006	SR-SS-302-0612-AVG	SR-SS-256-0006	SR-SS-254-0612
SR-SS-205-0006	SR-SS-205-0006	SR-SS-302-0612-D		SR-SS-255-0612
SR-SS-206-0006	SR-SS-206-0006	SR-SS-303-0612		SR-SS-255-0612-AVG
SR-SS-207-0006	SR-SS-207-0006	SR-SS-304-0612		SR-SS-255-0612-D
SR-SS-208-0006	SR-SS-208-0006	SR-SS-305-0612		SR-SS-256-0612
SR-SS-209-0006	SR-SS-209-0006	SR-SS-306-0612		
SR-SS-210-0006	SR-SS-210-0006	SR-SS-307-0612		
SR-SS-211-0006	SR-SS-211-0006			
SR-SS-212-0006	SR-SS-212-0006			
SR-SS-213-0006	SR-SS-213-0006			
SR-SS-214-0006	SR-SS-214-0006			
SR-SS-215-0006	SR-SS-215-0006			
SR-SS-301-0006				
SR-SS-302-0006				
SR-SS-303-0006				
SR-SS-304-0006				
SR-SS-305-0006				
SR-SS-306-0006				
SR-SS-307-0006				

Southern Range Area				
Surface Soils			Subsurface Soils	
SR-SS-001-000.5-20071019	SR-SS-049-000.5-20071106	SR-SS-259-0006-D	SR-SB-216-1224	SR-SS-228-0612
SR-SS-002-000.5-20071019	SR-SS-050-000.5-20071107	SR-SS-260-0006	SR-SB-217-1224	SR-SS-229-0612
SR-SS-003-000.5-20071019	SR-SS-051-000.5-20071107	SR-SS-261-0006	SR-SB-218-1224	SR-SS-230-0612
SR-SS-004-000.5-20071022	SR-SS-053-000.5-20071107	SR-SS-262-0006	SR-SB-219-1224	SR-SS-231-0612
SR-SS-007-000.5-20071022	SR-SS-054-000.5-20071107	SR-SS-263-0006	SR-SB-220-1224	SR-SS-232-0612
SR-SS-007-000.5-20071022-AVG	SR-SS-055-000.5-20071107	SR-SS-264-0006	SR-SB-221-1224	SR-SS-233-0612
SR-SS-007-000.5-20071022-D	SR-SS-056-000.5-20071107	SR-SS-265-0006	SR-SB-221-1224 SIEVE 20	SR-SS-233-0612-AVG
SR-SS-008-000.5-20071022	SR-SS-216-0006	SR-SS-266-0006	SR-SB-221-1224 SIEVE PAN	SR-SS-233-0612-D
SR-SS-009-000.5-20071022	SR-SS-217-0006	SR-SS-267-0006	SR-SB-222-1224	SR-SS-234-0612
SR-SS-010-000.5-20071022	SR-SS-217-0006-AVG	SR-SS-267-0006-AVG	SR-SB-222-1224-AVG	SR-SS-235-0612
SR-SS-011-000.5-20071018	SR-SS-217-0006-D	SR-SS-267-0006-D	SR-SB-222-1224-D	SR-SS-236-0612
SR-SS-013-000.5-20071022	SR-SS-218-0006	SR-SS-268-0006	SR-SB-223-1224	SR-SS-237-0612
SR-SS-014-000.5-20071022	SR-SS-219-0006	SR-SS-269-0006	SR-SB-223-1224-AVG	SR-SS-238-0612
SR-SS-015-000.5-20071022	SR-SS-220-0006	SR-SS-270-0006	SR-SB-223-1224-D	SR-SS-239-0612
SR-SS-016-000.5-20071022	SR-SS-221-0006	SR-SS-271-0006	SR-SB-224-1224	SR-SS-240-0612
SR-SS-017-000.5-20071022	SR-SS-221-006 SIEVE 20	SR-SS-272-0006	SR-SB-225-1224	SR-SS-257-0612
SR-SS-019-000.5-20071024	SR-SS-221-006 SIEVE PAN	SR-SS-273-0006	SR-SB-257-1224	SR-SS-258-0612
SR-SS-020-000.5-20071024	SR-SS-222-0006	SR-SS-274-0006	SR-SB-258-1224	SR-SS-259-0612
SR-SS-020-000.5-20071024-AVG	SR-SS-223-0006	SR-SS-275-0006	SR-SB-259-1224	SR-SS-260-0612
SR-SS-020-000.5-20071024-D	SR-SS-224-0006	SR-SS-276-0006	SR-SB-260-1224	SR-SS-260-0612-AVG
SR-SS-021-000.5-20071025	SR-SS-225-0006 SIEVE 20	SR-SS-276-0006-AVG	SR-SB-261-1224	SR-SS-260-0612-D
SR-SS-022-000.5-20071025	SR-SS-225-0006 SIEVE PAN	SR-SS-276-0006-D	SR-SB-262-1224	SR-SS-261-0612
SR-SS-023-000.5-20071025	SR-SS-225-0006-20180320	SR-SS-277-0006	SR-SB-263-1224	SR-SS-262-0612
SR-SS-024-000.5-20071025	SR-SS-226-0006	SR-SS-278-0006	SR-SS-216-0612	SR-SS-263-0612
SR-SS-025-000.5-20071024	SR-SS-226-0006-AVG	SR-SS-311-0006	SR-SS-217-0612	SR-SS-275-0612
SR-SS-026-000.5-20071024	SR-SS-226-0006-D	SR-SS-312-0006	SR-SS-218-0612	SR-SS-275-1224
SR-SS-027-000.5-20071024	SR-SS-227-0006	SR-SS-325-0006	SR-SS-219-0612	SR-SS-311-0612
SR-SS-028-000.5-20071024	SR-SS-228-0006	SR-SS-325-0006-AVG	SR-SS-220-0612	SR-SS-312-0612
SR-SS-029-000.5-20071024	SR-SS-229-0006	SR-SS-325-0006-D	SR-SS-221-0612	SR-SS-312-0612-AVG
SR-SS-030-000.5-20071024	SR-SS-230-0006	SR-SS-326-0006	SR-SS-221-0612 SIEVE 20	SR-SS-312-0612-D
SR-SS-031-000.5-20071024	SR-SS-231-0006	SR-SS-327-0006	SR-SS-221-0612 SIEVE PAN	
SR-SS-032-000.5-20071024	SR-SS-232-0006		SR-SS-222-0612	
SR-SS-033-000.5-20071025	SR-SS-233-0006		SR-SS-223-0612	
SR-SS-034-000.5-20071024	SR-SS-234-0006		SR-SS-224-0612	
SR-SS-035-000.5-20071025	SR-SS-235-0006		SR-SS-224-0612-AVG	
SR-SS-036-000.5-20071018	SR-SS-236-0006		SR-SS-224-0612-D	
SR-SS-040-000.5-20071106	SR-SS-237-0006		SR-SS-225-0612 SIEVE 20	
SR-SS-041-000.5-20071106	SR-SS-238-0006		SR-SS-225-0612 SIEVE PAN	
SR-SS-041-000.5-20071106-AVG	SR-SS-239-0006		SR-SS-225-0612-20180320	
SR-SS-041-000.5-20071106-D	SR-SS-240-0006		SR-SS-226-0612	
SR-SS-042-000.5-20071106	SR-SS-257-0006		SR-SS-226-1224	
SR-SS-043-000.5-20071106	SR-SS-258-0006		SR-SS-227-0612	
SR-SS-045-000.5-20071106	SR-SS-259-0006		SR-SS-227-0612-AVG	
SR-SS-047-000.5-20071106	SR-SS-259-0006-AVG		SR-SS-227-0612-D	



Legend

- High Tower Range Exposure Area
- Northern Range Exposure Area
- Skeet Range Shooting Exposure Area (PAHs)
- Southern Range Exposure Area
- cultural restricted area
- Skeet Range MRS
- Installation Boundary
- Architecture Points
- Historic Districts
- Culvert



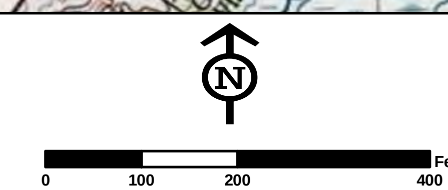


FIGURE 1-4
TARGET REMEDIATION ZONES
SKEET RANGE MRS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

TETRA TECH | 10/27/2020

Aerial Imagery 2013 ESRI map service
USA Topo Map 2013 ESRI map service

Coordinate System: North American Datum, 1983 VA South, Meters

NOR: G:\GIS_files\NASA WI\MXD\MBFR\SkeetRange\MBFR_CulturalResource.mxd MMC

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Appendix B
Area and Volume Calculations

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Client: NASA WALLOPS FLIGHT FACILITY		Project Number: 112G09133	
Subject: FUDS Project 9- Skeet Range MRS – Basis of Cost Estimates for FS Soil Alternatives			
By: LD and EC	Checked By: EC and JL	Approved By: EC	Date: 10/21/20 Rev: 01/27/21 Rev 02/05/21 after JL review

PURPOSE

The purpose of this calculation is to identify quantities for Alternative 2–Excavation and Off-Site Disposal and Alternative 3–Excavation, On-Site Consolidation Under Soil Cover, and Land Use Controls (LUCs). See Figures 2-2, 4-1, and 4-2 for the target remediation zones (TRZs) for the soil Chemicals of Concern (COCs): Lead, lead shot, and polycyclic aromatic hydrocarbons (PAHs). These calculations provide the basis for the cost estimate for remedial alternatives in Appendix C.

The spatial limits are based on soil data and physical features from the Site Investigation, supplemental investigation in the drainage area, and Remedial Investigation (Tetra Tech, 2009a, 200b, and 2018, respectively). For remedial alternative evaluation and discussion in this FS, surface soil is defined as the 0 to 1 foot below ground surface (bgs) and subsurface soil is below 1 foot bgs to the top of the water table (consistent with a practical, constructible 1-foot-lift/depth interval). Soil action is only needed for soil to depths of 1 foot bgs based on analytical data, human health risk assessment (HHRA) results, and ecological risk assessment (ERA) results. The spatial limits for excavation are (i) estimated based on exceedances of preliminary remediation goals (PRGs) as shown on Figures 1-3 through 1-6; (ii) delineated into Attainment Areas as shown on Figure 2-2; and (iii) developed into TRZ components as shown on Figures 2-2, 4-1, and 4-2. The actual limits will be determined based on confirmation sampling and limiting physical features.

REFERENCES

Use the data presented and summarized in the RI Report (Tetra Tech, 2020)—which also incorporates data from the previous investigations—to determine total excavation volumes, areas of disturbance, assumed volume of soil and sediment to be chemically treated on-site for lead stabilization if needed (Alternative 2), volume and weight of soil/sediment required for disposal (Alternative 2), volume of soil/sediment to be consolidated on-site (Alternative 3), the area and volume of the bio-engineered soil cover, including side slopes (Alternative 3). The calculations presented below are based on the Attainment Areas / TRZs for lead-, lead shot-, and PAH-contaminated soil shown on Figure 2-2 and developed into remedial alternative areas shown on Figure 4-1 (Alternative 2) and Figure 4-2 (Alternative 3).

CALCULATIONS

All excavations would be conducted to a depth of 1 foot bgs to address both human health (current/future) and ecological risks. There are no unacceptable risks or PRG exceedances associated with soil deeper than 1 foot bgs. Confirmation sampling would be performed at sidewalls and bottoms of excavations (see Confirmation Sampling).

Alternative 2–Excavation and Off-Site Disposal (see Figure 4-1)

All area measurements were estimated using GIS based on the boundaries depicted on Figure 2-2. Under Alternative 2, all TRZs would be excavated for off-site disposal. The areas would be backfilled and restored. No periodic or long-term actions would be required—that is, Alternative 2 would achieve No Further Action [NFA] with unrestricted use and unlimited exposure (UU/UE).

Client: NASA WALLOPS FLIGHT FACILITY		Project Number: 112G09133	
Subject: FUDS Project 9- Skeet Range MRS – Basis of Cost Estimates for FS Soil Alternatives			
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Calculations spreadsheet

	Range Exposure Area	TRZ	Media	Size (sf)	Size (acre)	Depth (ft)	Volume (cf)	Volume (BCY)	
Excavate for off-site disposal	Northern	L1	Soil	25600	0.59	1	25600	948	
	Northern	L1 Sediment	Sediment	1700	0.04	1	1700	63	
	High Tower	LS1	Soil	37000	0.85	1	37000	1370	
	Southern	L2	Soil	71000	1.63	1	71000	2630	
	Southern	LS2	Soil	75700	1.74	1	75700	2804	
	Southern	LS3	Soil	2800	0.06	1	2800	104	
	Southern/Skeet Shooting	PAH1	Soil	8400	0.19	1	8400	311	
	Southern	PAH2	Soil	780	0.02	1	780	29	
	Southern/Skeet Shooting	PAH3	Soil	4800	0.11	1	4800	178	
Overlaps	*Northern*	*L1 Sediment*	*Sediment*	*1700*	*0.04*	*1*	*1700*	*63*	
	Northern	*L1/LS1 overlap*	*Soil*	*7800*	*0.18*	*1*	*7800*	*289*	
	Southern	*L2/LS2 overlap*	*Soil*	*59400*	*1.36*	*1*	*59400*	*2200*	
		Totals-with-Overlaps-removed		**158880**	**3.65**	**1**	**158880**	**5884**	BCY
		" " " " " " " " Lead/LS only		144900	3.33	1	144900	5367	BCY
		" " " " " " " " " " PAHs only		13980	0.32	1	13980	518	BCY
	Weight to dispose of	Assume 1.5 tons/ BCY						8827	tons
	Volume to dispose of	Assume 20% fluff expansion after excavation						7061	LCY
	Import General fill for excavated areas = 1-ft excavated volume x 0.5							2942	BCY
	Import Topsoil for excavated areas = 1-foot-excavated area x 0.5							2942	BCY
	Wetland sediment area = L1 Sediment area							0.039	acre
	Area of disturbance (add 10% to remediation area, plus another 10% for staging, roads, etc.)							4.38	acre
								190656	sf
	seeding area = area of disturbance							4.38	acre
	On-Site Lead stabilization								
	Assume 25% of excavated soils require lead stabilization with phosphate reagent.							2207	tons
								1765	LCY

ft – foot or feet sf – square feet cf – cubic feet cy – cubic yard BCY – bank cubic yard LCY – loose cubic yard

Excavation for Disposal

The total volume of soil/sediment to be excavated (not double-counting overlaps) in Alternative 2 is 5,884 BCY. Note the TRZ L1 Sediment is within the TRZ L1. Assuming soil/sediment density at 110 pounds/cf (1.5 tons/cy), the excavated spoils would weigh 1.5 × 5,884 = 8,827 tons.

Productivity rates for excavation will range from 100 to 400 BCY/day depending on the TRZ size and haul distance (e.g., RSMeans 31 23 16.46-2420; common earth). Assuming a productivity rate of 250 BCY/day, the calendar day duration for the excavation component = 5,884 / 250 = 24 days. Additional time for hauling and eventual off-site transportation and disposal should be 30 calendar days depending on the number of truckloads each day (productivity assumed at off-site transport of 300 tons per day = 29 days). Direct-loading into dumps for disposal (with pre-characterization data) vs. hauling to staging area for load-out later (post-excavation characterization sampling) will be determined during the remedial design/work plan phase. Soil treatment for lead leachability based on waste characterization results (see below) would occur by mixing with phosphate reagent in-place prior to direct-loading; alternatively, soil can be treated at staging cells for later load-out.

Assume the soil/sediment volume post-excavation will expand 20 percent (%) to 5,884 × 1.2 = 7,061 LCY. If 20-cy roll-off containers or dumps will be used for hauling = 7,061 / 20 = 353 roll-offs / dumps.

Client: NASA WALLOPS FLIGHT FACILITY		Project Number: 112G09133	
Subject: FUDS Project 9- Skeet Range MRS – Basis of Cost Estimates for FS Soil Alternatives			
By: LD and EC	Checked By: EC and JL	Approved By: EC	Date: 10/21/20 Rev: 01/27/21 Rev 02/05/21 after JL review

E&S controls

An E&S Control Plan will be prepared as part of the remedial design/work plan. Assume area of disturbance by construction is 20% of AA(s)/TRZs = 3.65 acres × 1.2 = 4.38 acres (190,656 sf). This includes staging areas, construction roads, buffers around excavation areas, etc. Estimate silt fence perimeters around areas of disturbance. Approximately 4,000 feet considering staging areas, construction entrances, and the various excavation areas. Silt fence installation productivity is 1,300 feet per day (RSMeans 31 25 14.16-1000). Gross perimeters of each TRZ:

- L1/LS1 – 1,100 ft
- PAH1 – 430 ft
- PAH3 – 350 ft
- LS3 – 300 ft
- L2/LS2/PAH2 – 1,600 ft

Confirmation Sampling

Pre- or post-excavation confirmation sampling for PAH- and lead-contaminated soil includes off-site laboratory testing. No confirmation sampling for lead shot will be included. Sampling frequencies:

Sidewalls at 1 per 50-ft-perimeter = 4,000 ft / 50 ft = 80 sidewall confirmation samples

Bottom-excavation sampling should not be needed based on the risks calculated from the extensive data sets. However, if needed, would propose 1 per 6,750 sf (i.e., 1 per 250 cy for 1-ft-deep excavation or 1 per 80-ft-square for 1-ft-deep excavation).

Bottom-excavation at 1 per 6,750 sf = 158,880 sf / 6,750 sf = 24 bottom confirmation samples

Waste Characterization and Assumed Hazardous Lead Treatment

Pre- or post-excavation waste characterization samples will be collected according to the remedial action work plan (tbd). Assume pre-construction sampling at one waste characterization sample per 400 BCY (equivalent to 1 per 400 × 1.2 = 500 LCY), then the total number of waste characterization samples is 5,884 / 400 = 15 samples) for analysis of assumed full Toxicity Characteristic Leaching Procedure (TCLP), total petroleum hydrocarbons (TPH)–diesel range organics (DRO), and total benzene, toluene, ethylbenzene, and xylenes (BTEX). There are no RCRA TCLP criteria for PAHs. The waste characterization data are used to determine if wastes are hazardous by RCRA characteristic. The data can be used to determine if the excavated material can be used as alternate daily cover at the receiving landfill (for a lower tipping fee). TPH and BTEX data can be compared to Virginia Department of Transportation ‘clean fill’ criteria (50 mg/kg and 10 mg/kg, respectively) to evaluate use of material as construction fill elsewhere at the facility (e.g., road bedding material).

Based on data collected during the Site Investigation and RI, PAH-contaminated soil is assumed to be nonhazardous. However, it is conservatively assumed that up to 25% of lead- and lead shot-contaminated soils will not meet the RCRA characteristic TCLP criterion for lead of 5 milligrams per liter (mg/L) and, thus, would be classified as hazardous waste by characteristic. While lead leaching from soil to groundwater at the site is not a concern under natural conditions (as discussed in the RI and this FS), the TCLP test mimics more acidic conditions in a landfill. Soils with TCLP results above the criterion would be chemically stabilized on-site by mixing with a phosphate reagent (e.g., MAECTITE brand) to convert leachable lead into insoluble

Client: NASA WALLOPS FLIGHT FACILITY		Project Number: 112G09133	
Subject: FUDS Project 9- Skeet Range MRS – Basis of Cost Estimates for FS Soil Alternatives			
By: LD and EC	Checked By: EC and JL	Approved By: EC	Date: 10/21/20 Rev: 01/27/21 Rev 02/05/21 after JL review

minerals and mixed mineral forms (e.g., pyromorphite and apatite-barite); this would allow for off-site disposal as nonhazardous waste. The remaining 75% of excavated materials are assumed to pass TCLP lead.

Lead soil to be stabilized = 7,061 LCY × 0.25 = 1,765 LCY or 5884 BCY x 0.25 × 1.5 tons/BCY = 2,207 tons. Additional TCLP metals samples would be required following the stabilization to confirm TCLP lead leachate results are below the 5-mg/L-RCRA criterion.

Wetland / Biological

TRZ L1 Sediment is the 1,700-sf-portion of palustrine forested wetland lead-contaminated sediment within TRZ L1 for lead-contaminated soil. A jurisdictional wetland determination from USACE based on the 2018 wetland evaluation (Appendix F in the RI Report) may be required prior to construction. Administrative ARAR requirements would be completed with USACE for working in the wetland. A Biological Evaluation, Cultural Resources evaluation, and, e.g., a brown long-eared bat survey, will be required prior to design/construction for compliance with ARARs and agreements between NASA and USFWS.

No specific sediment dewatering or decanting will be required due to mixing of the relatively low volume of sediment with large volume of upland soils for on-site staging or direct load-out. The wetland is non-tidal based on elevations. Backfill with loamy sand. Propose no specific seeding or plantings and allow for natural reestablishment in this small area.

Restoration

Backfill all excavated areas to original grade with clean fill and topsoil. For the TRZ L1 Sediment portion of TRZ L1, use loamy fill without topsoil. Revegetate with native grasses (tbd with facility and regulators) during the remedial design/work plan phase. No specific wetland plantings are proposed—allow for natural revegetation of the 0.04-acre portion of the palustrine forested wetland. Almost 5,900 BCY of backfill and topsoil are estimated to restore the excavation and disturbed areas. Hauling productivity is the limiting rate: Assume 300 tons per day, 22 tons per truck; 8,830 tons / 300 = 30 calendar days. The assumed productivity rate for placing the backfill and topsoil is 550 LCY/day (RSMeans 31 23 23.15-7050). therefore, it is estimated to take 7,061 LCY / 550 LCY/day = 13 calendar days to complete the placement of fill and topsoil at the excavated areas and the soil cover.

Clean backfill and topsoil analyses: Lead, total BTEX, and TPH-DRO. One from each source.

Assume area of disturbance by construction is 20% greater than AA(s)/TRZs = 3.65 acres × 1.2 = 4.38 acres (190,656 sf). This includes staging areas, construction roads, buffers around excavation areas, etc. Fine grading and seeding has a typical productivity rate of 8,900 sy per day (RS Means 32 91 19.13-1000).

Alternative 3–Excavation, On-Site Consolidation under Soil Cover, and LUCs (see Figure 4-2)

All area measurements were estimated using GIS based on the boundaries depicted on Figure 2-2. The boundaries shown on Figure 4-2 were determined using the same GIS and the calculations herein (for the consolidation / soil cover area).

Under Alternative 3, TRZs L1 (includes L1 Sediment) and LS1 would be excavated from the High Tower and Northern Range Exposure Areas and consolidated in the Southern Range Exposure Area. TRZs PAH1, PAH3, and LS3 in the Southern Range Exposure Area also would also be excavated for consolidation. A

Client: NASA WALLOPS FLIGHT FACILITY		Project Number: 112G09133	
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portion of the L2-LS2 TRZs along the NOAA facility fence (referred to as, e.g., NOAA fence line buffer) would be excavated to allow for proper consolidation under the soil cover (i.e., space for the side slope of the soil cover). The excavated soil/sediment would be consolidated and graded in a ~1-foot-thick layer over the remaining contaminated soil in the Southern Range Exposure Area (i.e., TRZs L2, LS2, and PAH2).

Additional clean fill and topsoil materials would be imported to create a protective vegetated soil cover (see Figure 4-2): 1.5 foot of clean fill with 6 inches of topsoil. Jute mats would be installed to support the establishment of the vegetation. The vegetation—tbd native grass seeding mix specified by NASA—would add to the soil cover's integrity by providing root biomass, reducing erosion and runoff. The roots of the plants also produce root exudates, which typically encourage the growth of microbes that could be beneficial in reducing or stabilizing site-related contaminants. No specific compaction is required.

Calculations spreadsheet
(see below / next page)

Excavation for Consolidation
The total volume of soil/sediment to be excavated (not double-counting overlaps) in Alternative 3—for consolidation in the Southern Range Area—is 2,830 BCY. Note TRZ L1 Sediment is within the TRZ L1. Assuming soil/sediment density at 110 pounds/cf (1.5 tons/cy), the excavated spoils to be consolidated would weigh 1.5 × 2,830 = 4,244 tons.

Productivity rates for excavation will range from 100 to 400 BCY/day depending on the TRZ size and haul distance (e.g., RSMeans 31 23 16.46-2420; common earth). Assuming a productivity rate of 250 BCY/day, the duration for excavation = 2,830 / 250 = 12 days ≈ 2 weeks or ½ month. Soils will be direct-loaded into dumps to haul to the consolidation area in the Southern Range Area to be spread out in a 1-foot-thick layer. Spreading productivity is assumed at 550 LCY/day (RSMeans 31 23 23.15-7050).

Assume the soil/sediment volume post-excavation will expand 20% to 2,830 × 1.2 = 3,396 LCY. This 3,396 LCY of excavated soils will be hauled down to the Southern Range Exposure Area for consolidation on top of TRZs L2, LS2, and PAH2 (see Soil Cover, below). The hauling will be ongoing as the soils are excavated.

Client: NASA WALLOPS FLIGHT FACILITY		Project Number: 112G09133	
Subject: FUDS Project 9- Skeet Range MRS – Basis of Cost Estimates for FS Soil Alternatives			
By: LD and EC	Checked By: EC and JL	Approved By: EC	Date: 10/21/20 Rev: 01/27/21 Rev 02/05/21 after JL review

	Range Exposure Area	TRZ	Media	Size (sf)	Area (sf)	Size (acre)	Depth (ft)	Volume (cf)	Volume (BCY)	Vol (BCY)	Tons	
Excavate for consolidation	Northern	L1	Soil	25600	54800	0.59	1	25600	948	2030	1422	
	Northern	L1 Sediment	Sediment	1700		0.04	1	1700	63		94	
	High Tower	LS1	Soil	37000		0.85	1	37000	1370		2056	
	Southern/Skeet Shooting	PAH1	Soil	8400	13200	0.19	1	8400	311	489	467	
	Southern/Skeet Shooting	PAH3	Soil	4800		0.11	1	4800	178		267	
	Southern	LS3	Soil	2800	8400	0.06	1	2800	104	311	156	
	Southern	NOAA Buffer	Soil	5600		0.13	1	5600	207		311	
Overlaps	*Northern*	*L1 Sediment*	*Sediment*	*1700*	*9500*	*0.04*	*1*	*1700*	*63*	*352*	*94*	
	Northern	*L1/LS1 overlap*	*Soil*	*7800*		*0.18*	*1*	*7800*	*289*		*433*	
	Totals-Excavated-with-Overlaps-removed			**76400**	**76400**	**1.75**	**1**	**76400**	**2830**	**2830**	**4244**	
	Volume to spread	*Assume 20% fluff expansion after excavation*						***91680***	***3396***	*LCY*		
	Range Exposure Area	**TRZ**	**Media**	**Size (sf)**	**Area (sf)**	**Size (acre)**	**Depth (ft)**	**Volume (cf)**	**Volume (BCY)**	**Vol (BCY)**		
Leave to be covered	Southern	L2	Soil	71000	82480	1.63	1	71000	2630	3055	3944	tons
	Southern	LS2	Soil	75700		1.74	1	75700	2804		4206	tons
	Southern	PAH2	Soil	780		0.02	1	780	29		43	tons
Overlaps	*Southern*	*L2/LS2 overlap*	*Soil*	*59400*	*65000*	*1.36*	*1*	*59400*	*2200*	*2407*	*3300*	tons
	Southern	*NOAA Buffer*	*Soil*	*5600*		*0.13*	*1*	*5600*	*207*		*311*	tons
	Totals-left-in-place-to-be-covered			**82480**	**82480**	**1.89**	**1**	**82480**	**3055**	**3055**	**4582**	tons
				↓ Measured/Calculated by GIS ↓			↓ Calculated ↓					
Soil Cover	Southern Range	**Consolidation Area**		**85366**		**1.96**	***1.07***	***-foot-thick-spread*** *of* *LCY-of-Excavated-Soils*			9485	sy
	Import general fill for Cover (1.5-foot-thick)			85366		1.96	1.5	128049	4743	BCY	7114	tons
	Import topsoil for cover (0.5-foot-thick)						0.5	42683	1581	BCY	2371	tons
	Import general fill for side slopes (3:10 grade) *~1600-foot perimeter at 3 ft high and 10 ft out*			16000		0.37	0-3	24000	889	BCY	1333	tons
	TOTAL			**101366**		**2.33**		**194732**	**7212**	**BCY**	10818	tons
	Weight to consolidate	Assume 1.5 tons/ BCY							4244	tons		
	Volume to consolidate	Assume 20% fluff expansion after excavation							*3396*	LCY		
	Import General fill for excavated areas = 1-ft excavated volume x 0.5								1415	BCY	2122	tons
	Import Topsoil for excavated areas = 1-foot-excavated area x 0.5								1415	BCY	2122	tons
	Wetland sediment area = L1 Sediment area								0.039	acre		
	Area of disturbance (add 10% to remediation area, plus another 10% for staging, roads, etc.)								4.90	acre		
									213,319	sf	23702	sy
	seeding area = area of disturbance								4.46	acre		
									194,119	sf	21569	sy
	On-Site Lead stabilization											
	Assume 25% of excavated soils require lead stabilization with phosphate reagent.								2207	tons		
	(assume same total as Alternative 2 for both excavated-and-consolidated soil and soil covered-in-place).								1765	LCY		

Soil Cover

The 2,830 BCY (3,396 LCY) of soil excavated from TRZs L1 (includes L1 Sediment), LS1, PAH1, PAH3, LS3, and the NOAA fence line buffer would be consolidated as a ~1-foot-thick layer under a soil cover on top of TRZs L2, LS2, and PAH2 (minus the buffer space along the NOAA fence line). The area required to accommodate this consolidation is 85,366 sf or 1.96 acres ≈ 2 acres.

A 2-foot soil cover will be placed on top of the consolidated soils (see Figure 4-2): 1.5 foot of clean fill (4,743 BCY) with 6 inches of topsoil (1,581 BCY). Jute mats would be installed to support the establishment of the vegetation (native grass seeding mix specified by NASA). No specific compaction is required. Assume the sides/slopes of the consolidated material and overlying soil cover will have a maximum grade of 30% (tbd during design phase). With the approximate height above ground surface at (1 foot consolidated material) + (2 feet of cover material) = 3 feet, the slopes will run out 10 feet on each side. Considering the perimeter of the consolidated footprint is approximately 1,600 feet, the additional fill required for the slopes is roughly estimated at (3×10)/2 × 1600 = 24,000 = 889 cy. Therefore, the soil cover volume of imported backfill and topsoil = 4,743 + 1,581 + 889 = 7,212 BCY. The productivity rate to construct the cover as a process of

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Subject: FUDS Project 9- Skeet Range MRS – Basis of Cost Estimates for FS Soil Alternatives			
By: LD and EC	Checked By: EC and JL	Approved By: EC	Date: 10/21/20 Rev: 01/27/21 Rev 02/05/21 after JL review

placing backfill and topsoil is estimated at approximately 500 LCY/day (combination of 415 LCY/day [RSMeans 31 23 23.14-3320] and 550 LCY/day [RSMeans 31 23 23.15-7050]). Assuming the productivity rate of 500 LCY/day to consolidate the 3,396 LCY of excavated soils and construct/place the (7,212 BCY × 1.2 =) 8,655 LCY of soil cover backfill-and-topsoil yields approximately 24 calendar days of work.

E&S controls

An E&S Control Plan will be prepared as part of the remedial design/work plan. Assume area of disturbance by construction is an additional 20% of AA(s)/TRZs to be excavated plus the area of the consolidation area/cover = (1.75 + 1.96 acres) × 1.2 = 4.46 acres (194,119 sf). This includes staging areas, construction roads, buffers around excavation and consolidation areas, etc. Estimate silt fence perimeters around areas of disturbance: Approximately 4,000 feet considering staging areas, construction entrances, and the various excavation areas. Silt fence installation productivity is 1,300 feet per day (RSMeans 31 25 14.16-1000).

Confirmation Sampling

Pre- or post-excavation confirmation sampling for PAH- and lead-contaminated soil includes off-site laboratory testing. No confirmation sampling for lead shot will be included. Confirmation sampling is needed in the areas to be excavated for on-site consolidation (TRZs L1/LS1, PAH1, PAH3, L3, and the NOAA fence line buffer); to be conservative, the estimate includes confirmation sampling for the soils of TRZs L2/LS2 and PAH2—the Attainment Area soils to be left in place and covered by consolidated material and soil cover. Sampling frequencies, therefore, are the same as in Alternative 2:

Sidewalls at 1 per 50-ft-perimeter = 4,000 ft / 50 ft = 80 sidewall confirmation samples

Bottom-excavation sampling should not be needed based on the risks calculated from the extensive data sets. However, if needed, would propose the same as for Alternative 2, including for the Attainment Area soils of TRZs L2/LS2 and PAH3 to be left in place: 1 per 6,750 sf (i.e., 1 per 250 cy for 1-ft-deep excavation or 1 per 80-ft-square for 1-ft-deep excavation).

Bottom-excavation at 1 per 6,750 sf = 158,880 sf / 6,750 sf = 24 bottom confirmation samples

Waste Characterization and Assumed Hazardous Lead Treatment

Pre- or post-excavation limited-waste characterization samples will be collected according to the remedial action work plan (tbd). Assume pre-construction sampling at one waste characterization sample per 400 BCY (equivalent to 1 per 400 × 1.2 = 500 LCY), then the total number of waste characterization samples is 5,884 / 400 = 15 samples) for analysis of assumed only TCLP metals for lead. There are no RCRA TCLP criteria for PAHs. The waste characterization data are used to determine if the waste is hazardous by RCRA characteristic for lead. Soils under Alternative 3 would not to be disposed of off-site or used as fill elsewhere outside the site, so the additional waste characterization analyses typically requested by a TSD or useful by Virginia Department of Transportation are not necessary.

Based on data collected during the Site Investigation and RI, PAH-contaminated soil is assumed to be nonhazardous. However, it is conservatively assumed that up to 25% of lead- and lead shot-contaminated soils (to be excavated or left in place under this Alternative 3) would not meet the RCRA characteristic TCLP criterion for lead of 5 milligrams per liter (mg/L) and, thus, would be classified as hazardous waste by characteristic. While lead leaching from soil to groundwater at the site is not a concern under natural conditions (as discussed in the RI and this FS), the TCLP test mimics more acidic conditions in a landfill.

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Soils with TCLP results above the criterion would be chemically stabilized on-site by mixing with a phosphate reagent (e.g., MAECTITE brand) to convert leachable lead into insoluble minerals and mixed mineral forms (e.g., pyromorphite and apatite-barite); this would alleviate hazardous waste concerns for the on-site consolidation under a soil cover. The remaining 75% materials are assumed to pass TCLP lead.

Lead soil to be stabilized is assumed to be the same volume as that of Alternative 2 (to consider both excavated and left-in-place soils) = 7,061 LCY × 0.25 = 1,765 LCY or 5884 BCY x 0.25 × 1.5 tons/BCY = 2,207 tons. Additional TCLP metals samples would be required following the stabilization to confirm TCLP lead leachate results are below the 5-mg/L-RCRA criterion.

Restoration

Backfill all excavated areas to original grade with clean fill and topsoil. For TRZ L1 Sediment, use loamy fill without topsoil. Revegetate with native grasses (tbd with facility and regulators during the remedial design/ work plan phase). No specific wetland plantings are proposed—allow for natural revegetation of the 0.04-acre TRZ L1 Sediment. The soil cover will be seeded with the same native grasses as surrounding disturbed areas to be restored. Over 10,000 BCY of backfill and topsoil are estimated to backfill and restore the excavated areas (2,830 BCY), as well as to construct the soil cover (7,212 BCY). H Hauling productivity is the limiting rate: Assume 300 tons per day, 22 tons per truck; 15,60 tons / 300 = 50 calendar days. The assumed productivity rate for placing the backfill and topsoil is 550 LCY/day (RSMeans 31 23 23.15-7050); therefore, it is estimated to take 10,042 BCY × 1.2 = 12,050 LCY / 550 LCY/day = 22 calendar days to complete the placement of fill and topsoil at the excavated areas and the soil cover.

Clean backfill and topsoil analyses: Lead, total BTEX, and TPH-DRO. One from each source.

Assume area of disturbance by construction is an additional 20% of AA(s)/TRZs plus consolidation/cover area (including side slopes) = (1.75 acres + 2.33 acres) × 1.2 = 4.90 acres. This includes staging areas, construction roads, buffers around excavation areas, etc. Fine grading and seeding has an assumed productivity rate of 8,900 sy per day (RS Means 32 91 19.13-1000).

Appendix C
Cost Estimates

Table C-1 - Capital Cost Estimate
Alternative 2 - Excavation and Off-Site Disposal
FS for Skeet Range MRS - FUDS Project 9
NASA Wallops Flight Facility, Virginia

			Unit Cost				Extended Cost				
Item	Quantity	Unit	Subcontract	Material	Labor	Equipment	Subcontract	Material	Labor	Equipment	Subtotal
1 PROJECT PLANNING											
1.1 Prepare Documents & Plans	400	hr			$38.79		$0	$0	$15,516	$0	$15,516
2 PRE-CONSTRUCTION INVESTIGATION											
2.1 Sample Collection (3 persons for 5 days)	1	ls		$2,590.00	$491.55	$500.00	$0	$2,590	$492	$500	$3,582
2.2 Pre-Confirmation Samples/Analyses (Lead and PAHs)	104	ea	127.54				$13,264	$0	$0	$0	$13,264
2.3 Pre-Waste Characterization Samples/Analyses (Full TCLP, r, c, i, BTEX, and TPH-DRO)	15	ea	908.84				$13,633	$0	$0	$0	$13,633
3 MOBILIZATION, SITE PREPARATION, AND FIELD SUPPORT											
3.1 Office Trailer	3	mo				$455.86	$0	$0	$0	$1,368	$1,368
3.2 Field Office Support	3	mo		$293.34			$0	$880	$0	$0	$880
3.3 Storage Trailer	3	mo				$124.87	$0	$0	$0	$375	$375
3.4 Underground Utility Clearances	1	ls	4000.00				$4,000	$0	$0	$0	$4,000
3.5 Construction Survey Support	10	day			$424.62	$30.91	$0	$0	$4,246	$309	$4,555
3.6 Equipment Mobilization/Demobilization	6	ea			$208.94	$338.98	$0	$0	$1,254	$2,034	$3,288
3.7 Site Superintendent	3	mo			$8,229.76		$0	$0	$24,689	$0	$24,689
3.8 Site Health & Safety and QA/QC	3	mo			$6,827.04		$0	$0	$20,481	$0	$20,481
3.9 Archaeologist	1	mo			$6,827.04		$0	$0	$6,827	$0	$6,827
3.10 Materials Storage Pad, 25' X 25'	5	ls		$1,000.00	$250.00	$200.00	$0	$5,000	$1,250	$1,000	$7,250
3.11 Water Truck for Dust Control	1.25	mo				$4,000.00	$0	$0	$0	$5,000	$5,000
3.12 Water for Dust Suppression	4,000	gal		$0.03			$0	$120	$0	$0	$120
3.13 Temporary Access Roads, 4" gravel, geotextile	2	ls		6000.00			$0	$12,000	$0	$0	$12,000
3.14 Clear Site, cut & chip trees to 6" diam., grub stumps, ren	1.3	acre			$1,753.65	$2,557.31	$0	$0	$2,280	$3,325	$5,604
3.15 Clear & grub brush w dozer, ball and chain, medium clea	3.1	acre			$333.41	$997.00	$0	$0	$1,034	$3,091	$4,124
3.16 Erosion and Sedimentation Controls silt fence	3,000	feet		$0.41	$0.54	$0.14	$0	$1,230	$1,620	$420	$3,270
3.17 Erosion and Sedimentation Controls (slope/steep)	1,000	feet		$0.51	$0.68	$0.18	$0	$513	$675	$175	$1,363
4 DECONTAMINATION											
4.1 Equipment Decon Pad	1	ls		$4,500.00	$3,000.00	$725.00	$0	$4,500	$3,000	$725	$8,225
4.2 Decontamination Services	1	mo		$210.00	$1,800.00	$315.00	$0	$210	$1,800	$315	$2,325
4.3 Decon Water	4,000	gal		$0.20			$0	$800	$0	$0	$800
4.4 Decon Water Storage Tank,5,000 gallon	1	mo				$645.00	$0	$0	$0	$645	$645
4.5 Clean Water Storage Tank, 4,000 gallon	1	mo				$580.00	$0	$0	$0	$580	$580
4.6 Disposal of Decon Waste (liquid & solid)	1	ea	1000				$1,000	$0	$0	$0	$1,000
5 EXCAVATION AND DISPOSAL											
5.1 Excavator, 3/4 cy	5	week			$2,467.50	$3,360.00	$0	$0	$12,338	$16,800	$29,138
5.2 Site Labor, (3 laborers)	2	mo			$9,907.80		$0	$0	$19,816	$0	$19,816
5.3 Front End Loader, 3/4 cy bucket	5	week			$682.50	$721.88	$0	$0	$3,413	$3,609	$7,022
5.4 Dozer, Crawler (80hp)	5	week			$3,780.00	$5,250.00	$0	$0	$18,900	$26,250	$45,150
5.6 *Assumed* On-Site Haz Lead Soil Treatment (25%)	2,207	ton	25.00				$55,169	$0	$0	$0	$55,169
5.7 Check treated soil TCLP Lead sampling/analysis	4	ea	124.31		$38.79		$497	$0	$155	$0	$652
5.8 Off-Site Disposal, Non-Hazardous Soil	8,827	ton	85.00				$750,295	$0	$0	$0	$750,295
6 BACKFILL AND RESTORATION											

Table C-1 - Capital Cost Estimate
Alternative 2 - Excavation and Off-Site Disposal
FS for Skeet Range MRS - FUDS Project 9
NASA Wallops Flight Facility, Virginia

			Unit Cost				Extended Cost				
Item	**Quantity**	**Unit**	**Subcontract**	**Material**	**Labor**	**Equipment**	**Subcontract**	**Material**	**Labor**	**Equipment**	**Subtotal**
6.1 Clean backfill and topsoil (hauling and placement)	5,884	cy		$20.00	$2.80	$4.66	$0	$117,680	$16,475	$27,419	$161,575
6.2 Analytical for backfill and topsoil	4	ea	$252.81		$94.32		$1,011	$0	$377	$0	$1,389
6.3 Fine Grading and seeding, incl. lime, fert, and seed	21,184	sy		$0.57	$1.23	$0.21	$0	$12,075	$26,056	$4,449	$42,580
7 POST CONSTRUCTION COST											
7.1 Contractor Completion Report	200	hr			$38.79		$0	$0	$7,758	$0	$7,758
Subtotal							$838,869	$157,597	$190,451	$98,388	$1,285,305
Local Area Adjustments *(rates are auto-adjusted by RSMeans Costworks for Salisbury, MD, including open labor rates)*							*100.0%*	*100.0%*	*100.0%*	*100.0%*	
Subtotal							$838,869	$157,597	$190,451	$98,388	$1,285,305
Overhead on Labor Cost @ 30%									$57,135		$57,135
G & A on Labor Cost @ 10%									$19,045		$19,045
G & A on Material Cost @ 10%								$15,760			$15,760
G & A on Equipment Cost @ 10%										$9,839	$9,839
G & A on Subcontract Cost @ 10%							$83,887				$83,887
Tax on Materials and Equipment Cost @ 6%								$9,456		$5,903	$15,359
Total Direct Cost							$922,756	$182,813	$266,631	$114,130	$1,486,330
Indirects on Total Direct Cost @ 30%		(excluding transportation and disposal cost)									$220,810
Profit on Total Direct Cost @ 10%											$148,633
Subtotal											$1,855,773
Health & Safety Monitoring @ 2%		(includes air quality monitoring)									$37,115
Total Field Cost											$1,892,889
Contingency on Total Field Costs @ 20%											$378,578
Engineering on Total Field Cost @ 10%		(excluding transportation and disposal cost)									$114,259
TOTAL CAPITAL COST											**$2,385,726**

Sources: Similar projects, vendor quotes, and "RSMeans Costworks; Release Year 2020, Quarter 4 rates; Location adjusted for Salisbury, MD (218); Open shop labor.

Table C-2a - Present Value Over 30 Years
Alternative 3 - Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
FS for Skeet Range MRS - FUDS Project 9
NASA Wallops Flight Facility, Virginia

Year	Capital Cost	Annual Cost	Cost Every 5 Years	Total Year Cost	Annual Real Discount Rate	Present Value
0	$1,568,175	$0		$1,568,175	1.000	$1,568,175
1		$11,020		$11,020	0.996	$10,976
2		$11,020		$11,020	0.992	$10,932
3		$3,130		$3,130	0.988	$3,093
4		$3,130		$3,130	0.984	$3,080
5		$3,130	$23,000	$26,130	0.980	$25,614
6		$3,130		$3,130	0.976	$3,056
7		$3,130		$3,130	0.972	$3,044
8		$3,130		$3,130	0.969	$3,032
9		$3,130		$3,130	0.965	$3,020
10		$3,130	$23,000	$26,130	0.961	$25,107
11		$3,130		$3,130	0.957	$2,996
12		$3,130		$3,130	0.953	$2,984
13		$3,130		$3,130	0.949	$2,972
14		$3,130		$3,130	0.946	$2,960
15		$3,130	$23,000	$26,130	0.942	$24,611
16		$3,130		$3,130	0.938	$2,936
17		$3,130		$3,130	0.934	$2,925
18		$3,130		$3,130	0.931	$2,913
19		$3,130		$3,130	0.927	$2,901
20		$3,130	$23,000	$26,130	0.923	$24,125
21		$3,130		$3,130	0.920	$2,878
22		$3,130		$3,130	0.916	$2,867
23		$3,130		$3,130	0.912	$2,855
24		$3,130		$3,130	0.909	$2,844
25		$3,130	$23,000	$26,130	0.905	$23,648
26		$3,130		$3,130	0.901	$2,821
27		$3,130		$3,130	0.898	$2,810
28		$3,130		$3,130	0.894	$2,799
29		$3,130		$3,130	0.891	$2,788
30		$3,130	$23,000	$26,130	0.887	$23,181
					TOTAL PRESENT WORTH (30-YEARS)[(1)] =	**$1,800,943**

Notes:

1. A 30-year timeframe is used to provide a typical cost estimate for comparison. In reality, the operation and maintenance (O&M) will occur and the land use controls (LUCs) will occur in perpetuity. USEPA (2000) indicates the blanket use of USEPA's (1988) recommended 30-year-timeframe is no longer recommended. See Table C-2b for a 100-year timeframe present worth estimate.

The "Real" Discount Rate used to calculate the Present Value (PV) is timeframe dependent per the Office of Management and Budget (OMB), *Circular A-94, Appendix C, Revised December 2019, "Discount Rates for Cost Effectiveness, Lease Purchase, and Related Analysis" for Calendar Year 2020* . The rate is a forecast of real interest rates from which the inflation premium has been removed and based on current economic assumptions.

The information in this cost estimate is based on the best available information regarding the anticipated scope of the remedial alternative. Changes in the cost elements can occur as a result of new information and data collected. This is an order-of-magnitude engineering cost estimate that is expected to be within –30 to +50 percent of the actual project cost (per USEPA, 1988 and 2000).

USEPA, 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* . OSWER Directive 9355.3-01. EPA/540/G-89/004. October.

USEPA, 2000. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* . With the U.S. Army Corps of Engineers. OSWER 9355.0-75. EPA 540-R-00-002. July.

Table C-2b - Present Value Over 100 Years
Alternative 3 - Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
FS for Skeet Range MRS - FUDS Project 9
NASA Wallops Flight Facility, Virginia

Year	Capital Cost	Annual Cost	Cost Every 5 Years	Total Year Cost	Annual Real Discount Rate at 0.4%	Present Value
0	$1,568,175	$0		$1,568,175	1.000	$1,568,175
1		$11,020		$11,020	0.935	$10,299
2		$11,020		$11,020	0.992	$10,932
3		$3,130		$3,130	0.988	$3,093
4		$3,130		$3,130	0.984	$3,080
5		$3,130	$23,000	$26,130	0.980	$25,614
6		$3,130		$3,130	0.976	$3,056
7		$3,130		$3,130	0.972	$3,044
8		$3,130		$3,130	0.969	$3,032
9		$3,130		$3,130	0.965	$3,020
10		$3,130	$23,000	$26,130	0.961	$25,107
11		$3,130		$3,130	0.957	$2,996
12		$3,130		$3,130	0.953	$2,984
13		$3,130		$3,130	0.949	$2,972
14		$3,130		$3,130	0.946	$2,960
15		$3,130	$23,000	$26,130	0.942	$24,611
16		$3,130		$3,130	0.938	$2,936
17		$3,130		$3,130	0.934	$2,925
18		$3,130		$3,130	0.931	$2,913
19		$3,130		$3,130	0.927	$2,901
20		$3,130	$23,000	$26,130	0.923	$24,125
21		$3,130		$3,130	0.920	$2,878
22		$3,130		$3,130	0.916	$2,867
23		$3,130		$3,130	0.912	$2,855
24		$3,130		$3,130	0.909	$2,844
25		$3,130	$23,000	$26,130	0.905	$23,648
26		$3,130		$3,130	0.901	$2,821
27		$3,130		$3,130	0.898	$2,810
28		$3,130		$3,130	0.894	$2,799
29		$3,130		$3,130	0.891	$2,788
30		$3,130	$23,000	$26,130	0.887	$23,181

Table C-2b - Present Value Over 100 Years
Alternative 3 - Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
FS for Skeet Range MRS - FUDS Project 9
NASA Wallops Flight Facility, Virginia

Year	Capital Cost	Annual Cost	Cost Every 5 Years	Total Year Cost	Annual Real Discount Rate at 0.4%	Present Value
31		$3,130		$3,130	0.884	$2,766
32		$3,130		$3,130	0.880	$2,755
33		$3,130		$3,130	0.877	$2,744
34		$3,130		$3,130	0.873	$2,733
35		$3,130	$23,000	$26,130	0.870	$22,723
36		$3,130		$3,130	0.866	$2,711
37		$3,130		$3,130	0.863	$2,700
38		$3,130		$3,130	0.859	$2,689
39		$3,130		$3,130	0.856	$2,679
40		$3,130	$23,000	$26,130	0.852	$22,274
41		$3,130		$3,130	0.849	$2,657
42		$3,130		$3,130	0.846	$2,647
43		$3,130		$3,130	0.842	$2,636
44		$3,130		$3,130	0.839	$2,626
45		$3,130	$23,000	$26,130	0.836	$21,833
46		$3,130		$3,130	0.832	$2,605
47		$3,130		$3,130	0.829	$2,595
48		$3,130		$3,130	0.826	$2,584
49		$3,130		$3,130	0.822	$2,574
50		$3,130	$23,000	$26,130	0.819	$21,402
51		$3,130		$3,130	0.816	$2,553
52		$3,130		$3,130	0.813	$2,543
53		$3,130		$3,130	0.809	$2,533
54		$3,130		$3,130	0.806	$2,523
55		$3,130	$23,000	$26,130	0.803	$20,979
56		$3,130		$3,130	0.800	$2,503
57		$3,130		$3,130	0.796	$2,493
58		$3,130		$3,130	0.793	$2,483
59		$3,130		$3,130	0.790	$2,473
60		$3,130	$23,000	$26,130	0.787	$20,564
61		$3,130		$3,130	0.784	$2,454

Table C-2b - Present Value Over 100 Years
Alternative 3 - Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
FS for Skeet Range MRS - FUDS Project 9
NASA Wallops Flight Facility, Virginia

Year	Capital Cost	Annual Cost	Cost Every 5 Years	Total Year Cost	Annual Real Discount Rate at 0.4%	Present Value
62		$3,130		$3,130	0.781	$2,444
63		$3,130		$3,130	0.778	$2,434
64		$3,130		$3,130	0.775	$2,424
65		$3,130	$23,000	$26,130	0.771	$20,158
66		$3,130		$3,130	0.768	$2,405
67		$3,130		$3,130	0.765	$2,395
68		$3,130		$3,130	0.762	$2,386
69		$3,130		$3,130	0.759	$2,376
70		$3,130	$23,000	$26,130	0.756	$19,760
71		$3,130		$3,130	0.753	$2,357
72		$3,130		$3,130	0.750	$2,348
73		$3,130		$3,130	0.747	$2,339
74		$3,130		$3,130	0.744	$2,329
75		$3,130	$23,000	$26,130	0.741	$19,369
76		$3,130		$3,130	0.738	$2,311
77		$3,130		$3,130	0.735	$2,302
78		$3,130		$3,130	0.732	$2,293
79		$3,130		$3,130	0.730	$2,283
80		$3,130	$23,000	$26,130	0.727	$18,986
81		$3,130		$3,130	0.724	$2,265
82		$3,130		$3,130	0.721	$2,256
83		$3,130		$3,130	0.718	$2,247
84		$3,130		$3,130	0.715	$2,238
85		$3,130	$23,000	$26,130	0.712	$18,611
86		$3,130		$3,130	0.709	$2,220
87		$3,130		$3,130	0.707	$2,212
88		$3,130		$3,130	0.704	$2,203
89		$3,130		$3,130	0.701	$2,194
90		$3,130	$23,000	$26,130	0.698	$18,243
91		$3,130		$3,130	0.695	$2,177
92		$3,130		$3,130	0.693	$2,168

Table C-2b - Present Value Over 100 Years
Alternative 3 - Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
FS for Skeet Range MRS - FUDS Project 9
NASA Wallops Flight Facility, Virginia

Year	Capital Cost	Annual Cost	Cost Every 5 Years	Total Year Cost	Annual Real Discount Rate at 0.4%	Present Value
93		$3,130		$3,130	0.690	$2,159
94		$3,130		$3,130	0.687	$2,151
95		$3,130	$23,000	$26,130	0.684	$17,883
96		$3,130		$3,130	0.682	$2,134
97		$3,130		$3,130	0.679	$2,125
98		$3,130		$3,130	0.676	$2,117
99		$3,130		$3,130	0.674	$2,108
100		$3,130	$23,000	$26,130	0.671	$17,529
TOTAL PRESENT WORTH (100-YEARS)[1] =						**$2,216,240**

Notes:

1. The 100-year timeframe evaluated for Alternative 3 is used to provide a more realistic cost estimate considering the operation and maintenance (O&M) and land use controls (LUCs) will occur in perpetuity, per USEPA (2000).

The "Real" Discount Rate used to calculate the Present Value (PV) is timeframe dependent per the Office of Management and Budget (OMB), *Circular A-94, Appendix C, Revised December 2019, "Discount Rates for Cost Effectiveness, Lease Purchase, and Related Analysis" for Calendar Year 2020* . The rate is a forecast of real interest rates from which the inflation premium has been removed and based on current economic assumptions.

The information in this cost estimate is based on the best available information regarding the anticipated scope of the remedial alternative. Changes in the cost elements can occur as a result of new information and data collected. This is an order-of-magnitude engineering cost estimate that is expected to be within –30 to +50 percent of the actual project cost (per USEPA, 1988 and 2000).

USEPA, 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* . OSWER Directive 9355.3-01. EPA/540/G-89/004. October.

USEPA, 2000. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* . With the U.S. Army Corps of Engineers. OSWER 9355.0-75. EPA 540-R-00-002. July.

Table C-3 - Capital Cost Estimate
Alternative 3 - Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
FS for Skeet Range MRS - FUDS Project 9
NASA Wallops Flight Facility, Virginia

Item	Quantity	Unit	Unit Cost				Extended Cost				Subtotal
			Subcontract	Material	Labor	Equipment	Subcontract	Material	Labor	Equipment	
1 PROJECT PLANNING											
1.1 Prepare Documents & Plans	500	hr			$38.79		$0	$0	$19,395	$0	$19,395
2 PRE-CONSTRUCTION INVESTIGATION											
2.1 Sample Collection (3 persons for 5 days)	1	ls		$2,590.00	$491.55	$500.00	$0	$2,590	$492	$500	$3,582
2.2 Pre-Confirmation Samples/Analyses (Lead and PAHs)	104	ea	$127.54				$13,264	$0	$0	$0	$13,264
2.3 Pre-Waste Characterization Samples/Analyses (TCLP metals only)	15	ea	$125.00				$1,875	$0	$0	$0	$1,875
3 MOBILIZATION, SITE PREPARATION, AND FIELD SUPPORT											
3.1 Office Trailer	3	mo				$455.86	$0	$0	$0	$1,368	$1,368
3.2 Field Office Support	3	mo		$293.34			$0	$880	$0	$0	$880
3.3 Storage Trailer	3	mo				$124.87	$0	$0	$0	$375	$375
3.4 Underground Utility Clearances	1	ls	$4,000.00				$4,000	$0	$0	$0	$4,000
3.5 Construction Survey Support	15	day			$424.62	$30.91	$0	$0	$6,369	$464	$6,833
3.6 Equipment Mobilization/Demobilization	6	ea			$208.94	$338.98	$0	$0	$1,254	$2,034	$3,288
3.7 Site Superintendent	3	mo			$8,229.76		$0	$0	$24,689	$0	$24,689
3.8 Site Health & Safety and QA/QC	3	mo			$6,827.04		$0	$0	$20,481	$0	$20,481
3.9 Archaeologist	1	mo			$6,827.04		$0	$0	$6,827	$0	$6,827
3.10 Materials Storage Pad, 25' X 25'	5	ls		$1,000.00	$250.00	$200.00	$0	$5,000	$1,250	$1,000	$7,250
3.11 Water Truck for Dust Control	3.00	mo				$4,000.00	$0	$0	$0	$12,000	$12,000
3.12 Water for Dust Suppression	10,000	gal		$0.03			$0	$300	$0	$0	$300
3.13 Temporary Access Roads, 4" gravel, geotextile	2	ls		6000.00			$0	$12,000	$0	$0	$12,000
3.14 Clear Site, cut & chip trees to 6" diam., grub stumps, remov	1.3	acre			$1,753.65	$2,557.31	$0	$0	$2,280	$3,325	$5,604
3.15 Clear & grub brush w dozer, ball and chain, medium clearir	3.1	acre			$333.41	$997.00	$0	$0	$1,034	$3,091	$4,124
3.16 Erosion and Sedimentation Controls silt fence	3,000	feet		$0.41	$0.54	$0.14	$0	$1,230	$1,620	$420	$3,270
3.17 Erosion and Sedimentation Controls (slope/steep)	1,000	feet		$0.51	$0.68	$0.18	$0	$513	$675	$175	$1,363
4 DECONTAMINATION											
4.1 Equipment Decon Pad	1	ls		$4,500.00	$3,000.00	$725.00	$0	$4,500	$3,000	$725	$8,225
4.2 Decontamination Services	1	mo		$210.00	$1,800.00	$315.00	$0	$210	$1,800	$315	$2,325
4.3 Decon Water	4,000	gal		$0.20			$0	$800	$0	$0	$800
4.4 Decon Water Storage Tank,5,000 gallon	1	mo				$645.00	$0	$0	$0	$645	$645
4.5 Clean Water Storage Tank, 4,000 gallon	1	mo				$580.00	$0	$0	$0	$580	$580
4.6 Disposal of Decon Waste (liquid & solid)	1	ea	$1,000.00				$1,000	$0	$0	$0	$1,000
5 EXCAVATION AND CONSOLIDATION											
5.1 Excavator, 3/4 cy	4	week			$2,467.50	$3,360.00	$0	$0	$9,870	$13,440	$23,310
5.2 Site Labor, (3 laborers)	2	mo			$9,907.80		$0	$0	$19,816	$0	$19,816
5.3 Front End Loader, 3/4 cy bucket (250 cy/day)	5	week			$682.50	$721.88	$0	$0	$3,413	$3,609	$7,022
5.4 Dozer, Crawler (80hp)	5	week			$3,780.00	$5,250.00	$0	$0	$18,900	$26,250	$45,150
5.6 *Assumed* On-Site Haz Lead Soil Treatment (25%)	2,207	ton	25.00				$55,169	$0	$0	$0	$55,169
5.7 Check treated soil TCLP Lead sampling/analysis	4	ea	124.31		$38.79		$497	$0	$155	$0	$652

Table C-3 - Capital Cost Estimate
Alternative 3 - Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
FS for Skeet Range MRS - FUDS Project 9
NASA Wallops Flight Facility, Virginia

Item	Quantity	Unit	Unit Cost: Subcontract	Unit Cost: Material	Unit Cost: Labor	Unit Cost: Equipment	Extended Cost: Subcontract	Extended Cost: Material	Extended Cost: Labor	Extended Cost: Equipment	Subtotal
5.8 Off-Site Disposal, Non-Hazardous Soil	0	ton	85.00				$0	$0	$0	$0	$0
5.9 Hauling for consolidation	3,396	cy			$0.77	$1.34	$0	$0	$2,615	$4,551	$7,166
5.10 Consolidate and grade excavated soils (~1-foot-thick)	3,396	cy			$0.48	$1.94	$0	$0	$1,630	$6,588	$8,218
6 SOIL COVER											
6.1 Geotextile fabric (110% of footprint)	10,500	sy		$0.88	$0.17		$0	$9,240	$1,785	$0	$11,025
6.2 Vegetative Fill and Topsoil *(2 ft cover)*	6,323	cy		$20.00	$0.69	$1.53	$0	$126,460	$4,363	$9,674	$140,497
6.3 Fill and topsoil for 30% grade (3:10) side slopes	889	cy		$20.00	$0.69	$1.53	$0	$17,780	$613	$1,360	$19,754
6.4 Front End Loader, 3/4 cy bucket (465 cy/day)	2	week			$1,269.45	$1,342.69	$0	$0	$2,539	$2,685	$5,224
6.5 Site Labor, (3 laborers)	2	week			$2,476.95		$0	$0	$4,954	$0	$4,954
6.6 Jute mesh erosion-vegetation mats (120% footprint)	13,600	sy		$0.94	$0.27	$0.34	$0	$12,784	$3,672	$4,624	$21,080
7 BACKFILL AND RESTORATION											
7.1 Clean backfill and topsoil (hauling and placement)	2,830	cy		$20.00	$2.80	$4.66	$0	$56,600	$7,924	$13,188	$77,712
7.2 Analytical for backfill and topsoil	4	ea	$252.81		$94.32		$1,011	$0	$377	$0	$1,389
7.3 Fine Grading and seeding, incl. lime, fert, and seed	23,702	sy		$0.57	$1.23	$0.21	$0	$13,510	$29,153	$4,977	$47,641
8 POST CONSTRUCTION COST											
8.1 Contractor Completion Report	200	hr			$38.79		$0	$0	$7,758	$0	$7,758
8.2 LUC Remedial Design	200	hr			$38.79		$0	$0	$7,758	$0	$7,758
8.3 O&M Plan	200	hr			$38.79		$0	$0	$7,758	$0	$7,758
Subtotal							$76,816	$264,397	$226,218	$117,962	$685,394
Local Area Adjustments *(rates are auto-adjusted by RSMeans Costworks for Salisbury, MD, including open labor rates)*							*100.0%*	*100.0%*	*100.0%*	*100.0%*	
Subtotal							$76,816	$264,397	$226,218	$117,962	$685,394
Overhead on Labor Cost @ 30%									$67,865		$67,865
G & A on Labor Cost @ 10%									$22,622		$22,622
G & A on Material Cost @ 10%								$26,440			$26,440
G & A on Equipment Cost @ 10%										$11,796	$11,796
G & A on Subcontract Cost @ 10%							$7,682				$7,682
Tax on Materials and Equipment Cost @ 6%								$15,864		$7,078	$22,942
Total Direct Cost							$84,498	$306,700	$316,706	$136,836	$844,740
Indirects on Total Direct Cost @ 30% (excluding transportation and disposal cost)											$253,422
Profit on Total Direct Cost @ 10%											$84,474
Subtotal											$1,182,636

Table C-3 - Capital Cost Estimate
Alternative 3 - Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
FS for Skeet Range MRS - FUDS Project 9
NASA Wallops Flight Facility, Virginia

			Unit Cost				Extended Cost				
Item	**Quantity**	**Unit**	**Subcontract**	**Material**	**Labor**	**Equipment**	**Subcontract**	**Material**	**Labor**	**Equipment**	**Subtotal**
Health & Safety Monitoring @	2%	(includes air quality monitoring)									$23,653
Total Field Cost											$1,206,289
Contingency on Total Field Costs @	20%										$241,258
Engineering on Total Field Cost @	10%	(excluding transportation and disposal cost)									$120,629
TOTAL CAPITAL COST											**$1,568,175**

Sources: Similar projects, vendor quotes, and "RSMeans Costworks; Release Year 2020, Quarter 4 rates; Location adjusted for Salisbury, MD (218); Open shop labor.

Table C-4 - Future Costs
Alternative 3 - Excavation, On-Site Consolidation, Soil Cover, O&M, and LUCs
FS for Skeet Range MRS - FUDS Project 9
NASA Wallops Flight Facility, Virginia

Item	Item Cost Year 1	Item Cost Year 2	Item Cost Year 3 and Thereafter	Item Cost Every 5 years	Notes
LUCs / Soil Cover Inspection	$7,320	$7,320	$1,830		Quarterly during Years 1 and 2, then annually.
LUC Report	$3,200	$3,200	$800		
Soil Cover Operation and Maintenance	$500	$500	$500	$8,000	
Site Review				$15,000	Five-Year Review (assume it would be performed in conjunction with other remedy-in-place sites).
TOTALS	**$11,020**	**$11,020**	**$3,130**	**$23,000**	