Final Report

Formerly Used Defense Sites Remedial Investigation / Feasibility Study

Port Angeles Combat Range, Washington
FUDS Property No.: F0WA0033
Contract No.: W9128F-10-D-0058
Delivery Order: 0006

Military Munitions Response Program

March 2015

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Port Angeles Combat Range, Washington

Formerly Used Defense Sites - FUDS Property No.: F10WA0033

Remedial Investigation / Feasibility Study

Final Report

Military Munitions Response Program

March 2015

Prepared By:

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1.0 Executive Summary

The Port Angeles Combat Range (PACR) Remedial Investigation (RI) results indicate that sufficient data were collected to complete the RI and meet the objectives to determine the nature and extent of areas impacted by munitions related activities, and provide data sufficient to determine whether further action is required under the Military Munitions Response Program (MMRP) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The original munitions response site (MRS) is recommended to be split into three separate MRSs, based on the nature and extent of munitions and explosives of concern (MEC)/munitions debris (MD) within each MRS. The RI results were used to perform a Feasibility Study (FS) to develop the remedial action objective (RAO) and remedial action alternatives appropriate to each MRS. The results provide sufficient information for stakeholders to make decisions regarding the need for further action or No Department of Defense (DoD) Action Indicated (NDAI).

The PACR was used from 1943 through 1944 to train troops in various types of weapons use. The range was intended to be used for tactical firing problems and short-range known distance firing (200 to 300 yards). Munitions that were utilized at the site include 37millimeter (mm) and 75mm projectiles, 60mm and 81mm mortars, and various small arms.

The objective of the RI was to characterize the presence, nature, and extent of areas impacted by munitions related activities and assess the risk to human health and the environment from munitions constituents (MC) and the remaining explosive hazard from MEC. Remedial Investigation field activities were conducted from mid-October to mid-December 2013. Field activities included assisted visual surveys (AVS), geophysical surveys, and subsurface investigations using hand-held analog geophysical instruments and in-situ X-ray Fluorescence (XRF) screening for lead in soil. XRF screening was conducted at locations where natural features (e.g., natural berm feature) or small arms debris were found. During the RI, MEC, MD, and small arms debris were found. The high density of coverage during the AVS and geophysical surveys, along with the results of subsurface investigations and in-situ XRF screening for lead in soil have met the objectives of the investigation.

During the AVS, field teams surveyed the accessible acreage in the MRS, walking a total of 112 miles of transects during which approximately 250 features documenting general site conditions and metal debris (non-military related) were recorded. Only one MD item (frag) was identified during the AVS. No MEC was observed during the ASV.

A geophysical survey was performed within the impact areas that were open and accessible. Once the geophysical survey was completed and areas with high metallic anomaly densities (i.e., 250 anomalies or greater) were identified, a subsurface investigation was performed using hand-held analog geophysical instruments to define the nature and extent of MEC/MD. One hundred and twenty four (124) grids were established and investigated. One hundred forty seven (147) MD items and 25 small arms debris items were observed in 53 grids located in the northeastern portion of the MRS.

Five MEC items, M63 37mm high explosive (HE) projectiles, were discovered during the RI. The first four M63 37mm HE projectiles were destroyed in consolidated disposal operations; the fifth M63 37mm HE projectile was destroyed separately in an adjacent location within grid Q-09.

In-situ XRF screening for lead in soil was conducted in two locations where natural features (e.g., natural berm feature) were found, and in one location where small arms debris was found. XRF screening was utilized to assist the field investigation team to determine sampling locations for laboratory analysis. A conservative in-situ XRF lead screening level of 125 milligrams/kilogram (mg/kg) (compared to the State of Washington [WA] lead soil cleanup level of 250 mg/kg) was utilized. Sixty-eight (68) in-situ XRF screening locations were sampled in two natural features. Forty-five (45) in-situ XRF screening locations were also sampled where small arms debris was found. A total of 113 in-situ XRF screening samples were collected from the three locations. All in-situ XRF screening results for lead were below 125 mg/kg. Thus, no soil samples were collected for laboratory analysis.

Conceptual site models (CSMs) for MEC and MC were updated to evaluate the human and ecological receptors and exposure pathways reflecting the fate and transport of MEC and MC. MEC was discovered during the RI; consequently the exposure pathway for contact with MEC in surface soil (0 – 6 inches deep) is considered complete for all human receptors. The exposure pathway for contact with MEC in subsurface soil (> 6 inches deep) is potentially complete.

If MEC are present in damaged condition, MC could potentially be released to the environment; however, based on historical investigations and the 2013 RI, the potential for human and ecological exposure to MC is likely very low. There is some degree of uncertainty associated with potential MEC items which could remain buried; however, all current information suggests that the soil exposure pathway for MC is likely incomplete or likely insignificant.

For organization and discussion purposes, the PACR parent MRS is discussed as three MRSs based on the different levels of risk as determined by the types and distribution of MEC/MD within each area; however, these three areas have not been formally designated as MRSs in this RI/FS report The first MRS, comprising 4% of the original PACR parent MRS, is recommended to be carried forward and retain the Range Complex No. 1 MRS designation. This 105.7-acre MRS comprises parcels encompassing the identified impact areas and surrounding terrain. The second MRS is designated the Range Complex No. 1 (a) MRS. This 1,286.5-acre MRS includes the areas adjacent to the delineated impact areas (i.e., the Range Complex No. 1 MRS). The third MRS is designated the Range Complex No. 1 (b) MRS. This 1,238.5-acre MRS is comprised of property within the Olympic National Park (ONP) that was not investigated because a programmatic agreement to conduct investigations and remedial actions between the National Park Service (NPS) and the DoD does not exist. The area within the ONP is at the furthest extents of the range safety buffer. Based on topography and the typical configuration of the munitions identified during the RI there is a low probability that munitions are present within the ONP.

RAOs for each MRS are identified and provide a basis for developing the remedial action alternatives that may be selected to address any possible remaining explosive hazards. Because there were no areas impacted by MC identified during the RI, alternatives addressing MC were not evaluated. General response actions applicable to one or more of the PACR Complex MRSs include a No Action (NA) alternative as required under CERCLA, Land Use Controls (LUCs), surface clearance, and subsurface clearance remedial actions. For purposes of the detailed analysis of alternatives, magnetometer and dig (mag and dig) was selected and used as a representative technology applicable for the subsurface clearance alternatives. The specific technology best suited for each clearance area will be selected during the remedial design.

The general response actions were selected individually or in combination to develop remedial action alternatives that apply to the Range Complex No. 1 MRS as follows:

- Alternative 1 – NA (cost to complete $0)
- Alternative 2 – LUCs for site visitors and site workers (cost to complete $501.1K)
- Alternative 3 – Surface clearance and LUCs (cost to complete $1,133.9K)
- Alternative 4 – Surface clearance, subsurface clearance, and LUCs (cost to complete $2,517.5K)
- Alternative 5 – Surface clearance, subsurface clearance, tree survey and clearance, and LUCs (cost to complete $3,195.7K)

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2.0 Introduction

The DoD has established the MMRP to address DoD sites suspected of containing MEC or MC. Under the MMRP, the United States Army Corps of Engineers (USACE) is conducting environmental response activities at Formerly Used Defense Sites (FUDS) for the Army, DoD's Executive Agent for the FUDS program.

The USACE must comply with the Defense Environmental Response Program (DERP) statute (10 United States Code [USC] 2701 et seq.), the Comprehensive Environmental Response Compensation, and Liability Act (CERCLA, 42 USC § 9601 et seq., Executive Orders (EOs) 12580 and 13016, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and all applicable DoD (e.g., DoD Management Guidance for the DERP [28 September 2001]) and Army policies in managing and executing the FUDS program. Because of the linkages between the DERP and CERCLA and the delegation of certain Presidential authorities under CERCLA to DoD, CERCLA is DoD's preferred framework for environmental restoration.

This RI/FS was conducted under contract to the USACE, Omaha District in accordance with Contract No. W9128F-10-D-0058, Task Order 006, and the USACE Statement of Objectives dated June 2012. This RI/FS presents the results of the field surveys and results of sampling and analysis and presents remedial alternatives to provide decision-makers with an appropriate range of options and sufficient information to compare and select alternatives.

2.1 Purpose

This RI/FS was conducted in support of the MMRP at the Range Complex No. 1 MRS at the former PACR, WA. Previous work at this MRS consists of research of historical documents, and preparation of an Inventory Project Report (INPR), an Archive Search Report (ASR), an ASR Supplement, and a Site Inspection (SI). The Range Complex No. 1 MRS was established at the conclusion of the SI and was recommended for further characterization in an RI and if needed and a FS to identify and analyze remedial action alternatives.

2.1.1 Report Outline

The contents and order of presentation of this RI/FS report includes the following sections and appendices:

Section 1.0 Executive Summary

Section 2.0 Introduction

Section 3.0 Project Remedial Response Objectives

Section 4.0 Characterization of MEC and MC

Section 5.0 Revised Conceptual Site Models and Remedial Investigation Results

Section 6.0 Contaminant Fate and Transport for MEC and MC

Section 7.0 Baseline Risk Assessment for MC and Hazard Assessment for MEC

Section 8.0 Summary of Results

Section 9.0 Identification and Screening Technologies for MEC and MC

Section 10.0 Development and Screening of Alternatives

Section 11.0 Detailed Analyses of Alternatives

Section 12.0 References

Appendices:

Appendix A Definitions

Appendix B Abbreviations and Acronyms

Appendix C Photo Documentation Log

Appendix D Survey Control

Appendix E Field Notes and Forms

Appendix F Geophysical Investigation Quality Control Data

Appendix G Instrument Verification Memorandum

Appendix H Ordnance Technical Data Sheets

Appendix I Demilitarization Documentation

Appendix J Summary of Lead in Soils - X-ray Fluorescence Screening Data

Appendix K Visual Sampling Plan Reports

Appendix L Munitions and Explosives of Concern Hazard Assessment Tables

Appendix M Munitions Response Site Prioritization Protocol Tables

2.2 Property Description and Problem Identification

The following subsections describe the PACR RI project, problem identification, and access controls and restrictions, as well as current and future land use at the PACR.

2.2.1 Property Description

The PACR FUDS property No.: F10WA0033 is located approximately seven miles southeast of the City of Port Angeles, in Clallam County, Washington. The PACR is partially located in Township 29 North, Range 5 West – Sections 5, 8, and 17 of the Willamette Meridian (**Figure 2-1**). The PACR is included in the MMRP Inventory in the Defense Environmental Programs Annual Report to Congress Fiscal Year 2011 (DENIX, 2012) under Federal Facility Identification number WA09799F318400 with range information as identified in **Table 2-1** below (DENIX, 2009).

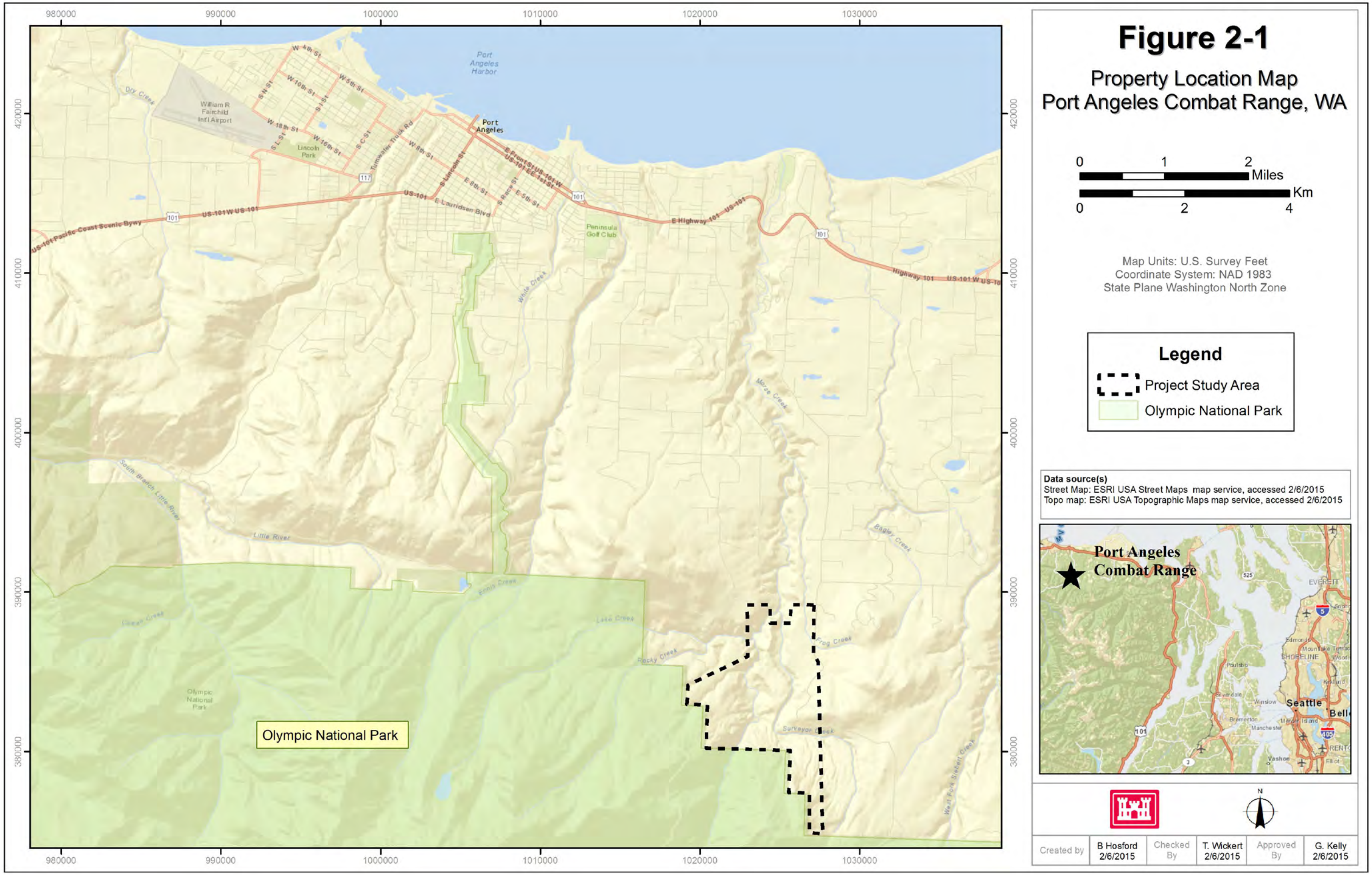
Figure 2-1
Property Location Map
Port Angeles Combat Range, WA
0 1 2 Miles
0 2 4 Km
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
Project Study Area
Olympic National Park
Data source(s)
Street Map: ESRI USA Street Maps map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Port Angeles Combat Range
Seattle
Olympic National Park
Port Angeles Harbor
Port Angeles
Created by
B Hosford 2/6/2015
Checked By
T. Wickert 2/6/2015
Approved By
G. Kelly 2/6/2015

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Table 2-1 Defense Environmental Restoration Programs Annual Report to Congress, Fiscal Year 2007, Site Inventory – Port Angeles Combat Range

Site ID*	RAC Score	Nearest City	Landowner Name	Ownership Interest	Range Total Acreage	Land Use Restrictions	Land Use Access Controls
01OEW	2	Port Angeles	Other / Federal Government	No Data Available	2,629	No Data Available	No Data Available

Note:
* Information presented in this table is per the SI Report
RAC = Risk Assessment Code

2.2.2 Buildings and Man-Made Features

There are 313 buildings within two miles of the MRS including primary residences on privately owned property within the MRS. There are no schools or hospitals with two miles of the MRS.

The private properties are served by electrical and phone utilities that branch off from the main lines along Deer Creek Road.

2.2.3 Current and Future Land Uses

The PACR is primarily maintained as a protected watershed for the City of Port Angeles, for timber production, as a National Park, and contains private residences (**Figure 2-2** and **Figure 2-3**). During the hunting season, the field team saw evidence of deer hunting and encountered numerous hunters each day while conducting the field investigation. The field team also saw and heard occasional evidence of recreational target shooting (e.g., improvised targets).

The closest population center is the City of Port Angeles, WA located approximately seven miles to the northwest of the PACR. The 2010 census population for the City of Port Angeles is 19,038. The 2010 population density for Clallam County is 40.4 persons per square mile (USCB, 2010).

The Census Block Group closest to the northern boundary of the PACR has a population density of 126 persons per square mile. Estimated populations within a four-mile radius and two-mile radius of the PACR property boundary are 3,887 and 1,064, respectively. The estimated numbers of households within a four-mile radius and two-mile radius of the PACR property boundary are 1,769 and 496, respectively (**Figure 2-4**).

The future use of the PACR is anticipated to be the same or very similar to the current use. Parts of the PACR will continue to be maintained as a protected watershed for the City of Port Angeles. Manke Timber Corporation owns eight parcels with the PACR and the Green Crow Company manages one parcel for timber harvesting.

Additional residential development in privately owned portions of the site should be anticipated. Future plans include the continuation of forest management, hunting, and possibly fish and wildlife conservation.

2.2.4 Access Controls and/or Restrictions

There are a number of land owners and leaseholders associated with the PACR and vicinity. These owners and lessees are within the FUDS boundary and include the City of Port Angeles, Clallam County, Washington Department of Natural Resources (WDNR) and private individuals or corporations (e.g., Manke Timber Corporation). A significant portion of the PACR is owned and maintained as a watershed for Port Angeles. The City permits cattle grazing in some areas. According to the ASR, no land in the PACR is owned by any DoD or other federal agency (USACE, 1996).

Right of Entry (ROE) was not obtained by the USACE during the RI for the following areas:

- **Parcel 47730** (87.2 acres) - located in the southeast corner of the PACR
- **Parcel 47501** (3.9 acres) - located on the eastern boundary of the PACR
- **Parcel 47404** (14.5 acres) - located in the northeastern corner of the PACR
- **ONP** (1,238.5 acres) – located in the southern portion of the PACR. The acreage within the ONP was not investigated because the NPS and the DoD do not have a programmatic agreement to address MMRP sites.

Refer to **Figure 2-3** for the location of the ONP and parcels where ROE was not obtained during the RI.

The MRS is accessible to the general public on the east side from the Deer Park Road side of the MRS. During the RI field investigation in 2013, barbed wire fencing was observed along the Deer Park Road boundary in the northern portion of the PACR. The fencing was in poor condition and was propped up in places. A few munitions hazards warning signs are still present within the MRS. The MRS is also accessible from Snow Ridge Road on the west side of the MRS. The field teams were able to walk into the MRS along a logging easement maintained by Manke Timber Corporation. The MRS is not accessible from Hurricane Ridge Road on the southwest side of the MRS. The field team tried to access the MRS from multiple access points along Hurricane Ridge Road; however, the terrain was too steep and treacherous for entry.

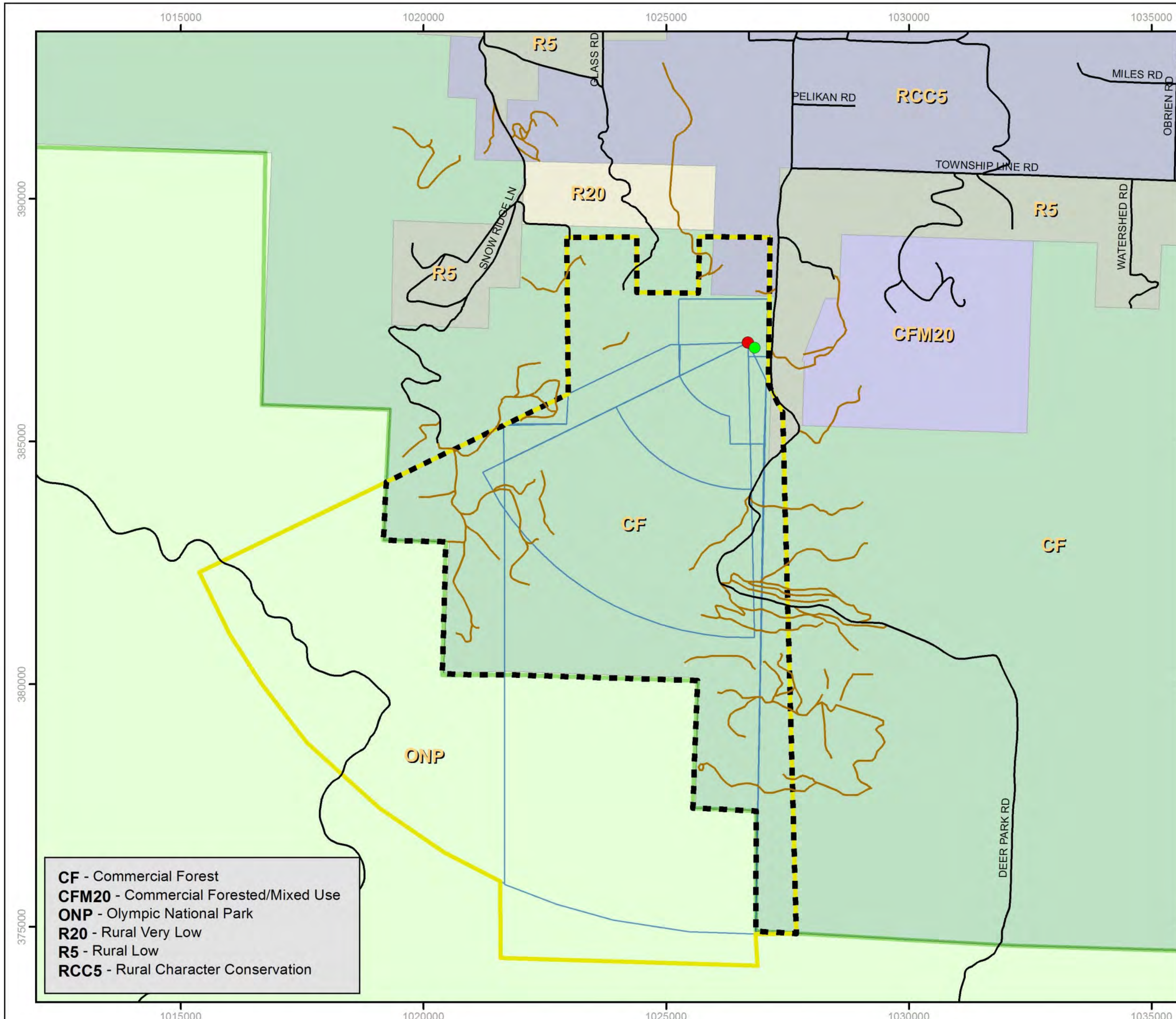

Figure 2-2

Land Status and Surrounding Areas Port Angeles Combat Range, WA

Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone

Legend

- Roads
- Unimproved Roads
- ASR Literal Firing Point
- Approximate Firing Point
- Range Complex No. 1
- Project Study Area
- PACR MRS Boundary
- Olympic National Park

Zoning: CF, CFM20, ONP, R20, R5, RCC5

Data source(s)
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Zoning: Clallam County WA, http://www.clallam.net, accessed 7/19/2012

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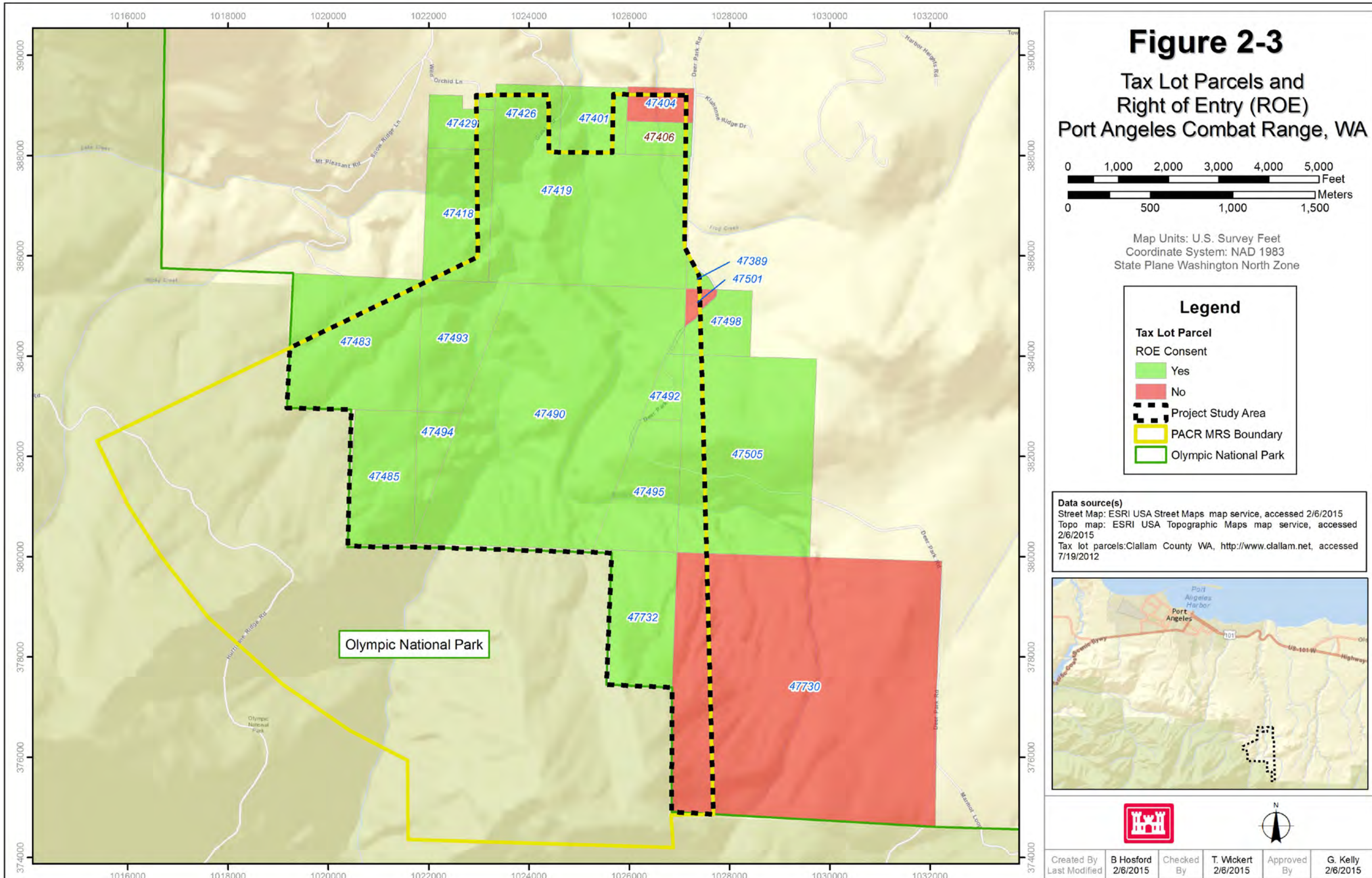
Figure 2-3
Tax Lot Parcels and
Right of Entry (ROE)
Port Angeles Combat Range, WA
0 1,000 2,000 3,000 4,000 5,000
Feet
Meters
0 500 1,000 1,500
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
Tax Lot Parcel
ROE Consent
Yes
No
Project Study Area
PACR MRS Boundary
Olympic National Park
Data source(s)
Street Map: ESRI USA Street Maps map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Tax lot parcels:Clallam County WA, http://www.clallam.net, accessed 7/19/2012
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T. Wickert 2/6/2015
Approved By
G. Kelly 2/6/2015
Olympic National Park
47404
47406
47426
47401
47429
47419
47418
47389
47501
47498
47483
47493
47492
47490
47494
47505
47485
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378000
376000
374000
Port Angeles Harbor
Port Angeles

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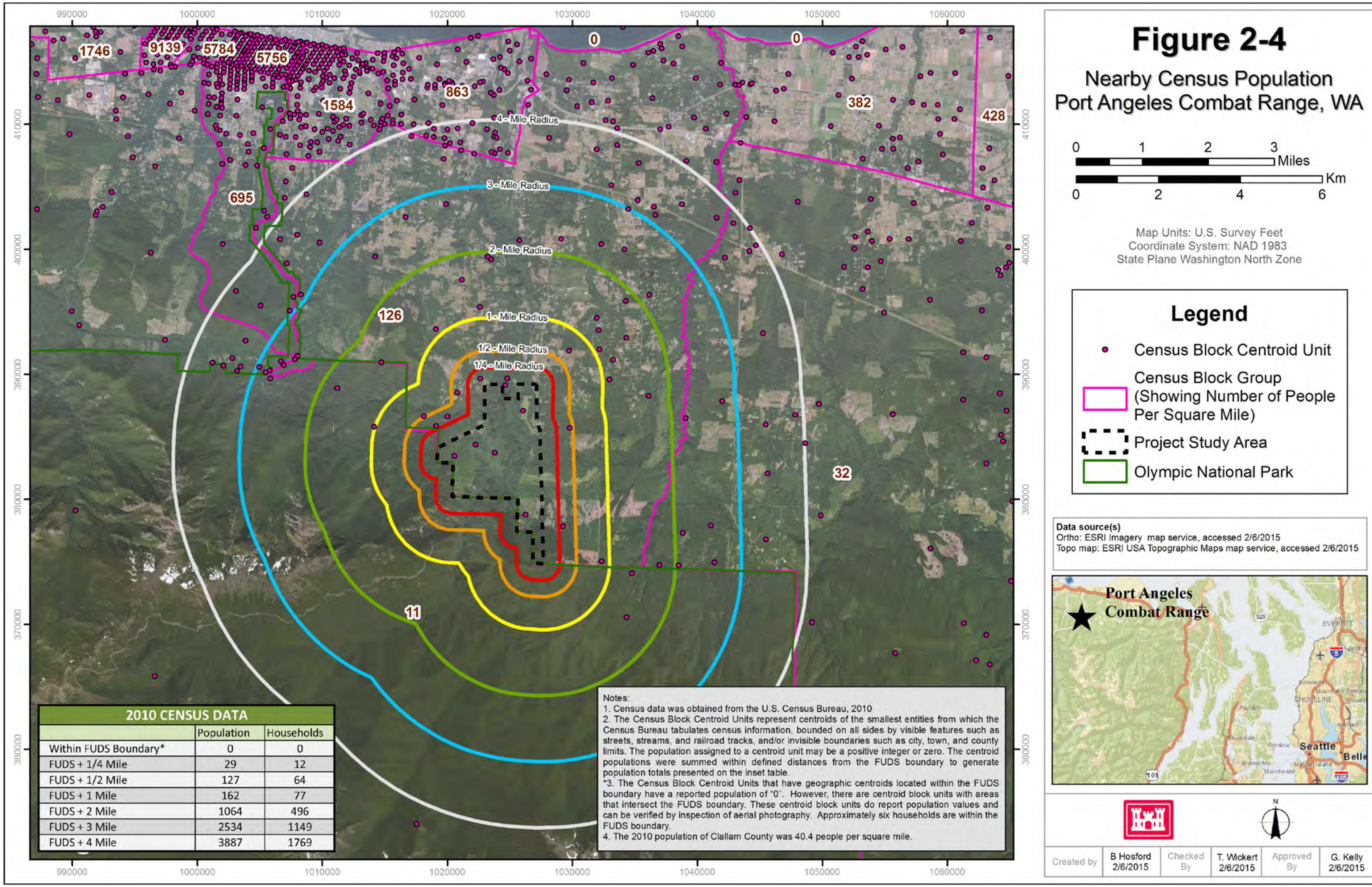

2010 CENSUS DATA		
	Population	Households
Within FUDS Boundary*	0	0
FUDS + 1/4 Mile	29	12
FUDS + 1/2 Mile	127	64
FUDS + 1 Mile	162	77
FUDS + 2 Mile	1064	496
FUDS + 3 Mile	2534	1149
FUDS + 4 Mile	3887	1769

Notes:
1. Census data was obtained from the U.S. Census Bureau, 2010
2. The Census Block Centroid Units represent centroids of the smallest entities from which the Census Bureau tabulates census information, bounded on all sides by visible features such as streets, streams, and railroad tracks, and/or invisible boundaries such as city, town, and county limits. The population assigned to a centroid unit may be a positive integer or zero. The centroid populations were summed within defined distances from the FUDS boundary to generate population totals presented on the inset table.
*3. The Census Block Centroid Units that have geographic centroids located within the FUDS boundary have a reported population of "0". However, there are centroid block units with areas that intersect the FUDS boundary. These centroid block units do report population values and can be verified by inspection of aerial photography. Approximately six households are within the FUDS boundary.
4. The 2010 population of Clallam County was 40.4 people per square mile.

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2.2.5 Climate

The MRS area climate is tempered by winds from the Pacific Ocean. Summers are warm but hot days are rare. In winter, temperatures are cool; however, freezing temperatures and snow are infrequent except in the mountains (USACE, 1996). The average maximum high temperature within the City of Port Angeles occurs in July at 68.4 degrees Fahrenheit (°F) and the minimum average low temperature occurs in January at 34.1°F. The average annual precipitation is 25.0 inches, which occurs primarily between October and April. Average total snowfall is 4.1 inches (WRCC, 2013). See **Table 2-2** for monthly averages.

Table 2-2 Climate Table – Port Angeles Combat Range

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (ºF)	44.9	47.4	50.2	54.9	60.3	64.2	68.4	67.9	65.0	57.1	49.6	45.9	56.3
Average Min. Temperature (ºF)	34.1	35.4	36.9	40.3	44.9	49.1	51.7	52.0	48.7	43.4	38.2	35.5	42.5
Average Total Rainfall (inches)	3.9	2.7	2.1	1.3	1.3	0.9	0.5	0.8	1.1	2.5	4.0	4.3	25.0
Average Total Snow Fall (in.)	1.7	0.9	0.4	0	0	0	0	0	0	0	0.3	0.8	4.1
Average Snow Depth (in.)	0	0	0	0	0	0	0	0	0	0	0	0	0

2.2.6 Topography

The Range Complex No. 1 MRS is located within the State of WA and the Olympic Peninsula. The land is hilly to mountainous. The northern portion of the Range Complex No. 1 MRS contains areas of meadowland/grassland, but other areas are densely forested. The minimum and maximum elevations of the MRS are approximately 700 feet in the north and 3,541 feet in the south at Round Mountain. Deep erosion features associated with Morse and Surveyor Creeks are present at the MRS and likely follow the same channels present during historical U.S. Army training activities. Topography, including surface elevations and prominent features, is illustrated on **Figure 2-5**.

2.2.7 Hydrology

Three creeks transect the MRS flowing from south to north; Surveyor Creek, Frog Creek, and Morse Creek (**Figure 2-6**). These creeks flow north toward the City of Port Angeles. Property associated with the MRS serves as a watershed for the City of Port Angeles. A surface water intake is located at the location labeled as “Port Angeles Dam” on **Figure 2-6** and the second intake is located approximately 1,200 feet downstream of the dam. The intake at “Port Angeles Dam” is within the MRS boundary.

The United States Fish & Wildlife Service (USFWS) National Wetlands Inventory indicates a 0.43-acre wetland in the southern portion of the large meadow present within the MRS. The wetland is classified as freshwater emergent. It is specifically described as a palustrine, emergent, persistent, seasonally flooded wetland. Wetlands of this type are dominated by trees, shrubs, emergents, and mosses or lichens. Surface water is present for extended periods, especially early in the growing season (USFWS, 2013). The wetland was not investigated, as no ROE was granted for the privately owned parcel in which it is located (parcel 47501).

2.2.8 Soil and Vegetation

Soils present at the MRS are Elwha gravelly sandy loam, Neilton very gravelly sandy loam, Puget silt loam, and Terbies very gravelly sandy loam (NRCS, 2007) (**Figure 2-7**). During the 2008 SI sampling, the surface soils were described as consisting of silty sand (Shaw, 2009).

Vegetation on the MRS consists of primarily second growth fir and alder with some cedar trees. In forested areas, the MRS has very dense undergrowth that makes access difficult. Recently logged areas have very dense growth of small trees and shrubs that makes these areas nearly inaccessible.

Review of historical aerial photographs indicates that the areas of meadowland/grassland have been present since at least 1939, and contained target features used for artillery practice. The southern portion of the MRS (buffer zone) is located within the ONP.

2.2.9 Geology

Geology of the area is controlled by the converging of two tectonic plates (Juan de Fuca and North American plates). Underlying the MRS are accreted Tertiary sediments and pillow basalt rocks that were once on the floor of the Pacific Ocean. During the Pleistocene Epoch, colder climates brought about glaciations over much of the Olympic Peninsula and Puget Lowland, leaving thick glacial outwash deposits over older rocks (NRCS, 2007). North of the MRS, these glacial outwash deposits pinch out and bedrock is covered by deposits of rocky alluvium on hillsides and by sands and gravels with silt in areas of low relief (Shaw, 2009).

2.2.10 Hydrogeology

Shallow groundwater in the region occurs in gravelly units within the glacial outwash deposits. In the MRS vicinity groundwater occurs within sand and gravel units that overlie the bedrock. Based on well logs, groundwater occurs in these units at a depth ranging from 50 to 120 feet. Regional groundwater flow is to the north from the highlands to the Strait of Juan de Fuca. A site resident indicated that depth to groundwater at his domestic well was approximately 18 feet below ground surface (bgs). No well log is available to determine the well depth or geology. Because of the surface streams in the area, shallow groundwater flow within the MRS is likely toward nearby streams where it is assumed to discharge (Shaw, 2009).

Drinking water in the area is obtained from the Clallam County Public Utility District (PUD) No. 1 and private water supply wells. Clallam County PUD No. 1 obtains water from Morse Creek at two water intake structures. There are two private domestic wells located in the northern portion of the MRS (Shaw, 2009). The total depth of the Mortensen well is 285 feet bgs and the Whitcomb well is 116 feet bgs. Static water levels were recorded as 0 feet and 30 feet below top of casing (btoc), respectively. Both wells were installed by Louie’s Well Drilling Inc. (WDOE, 2013).

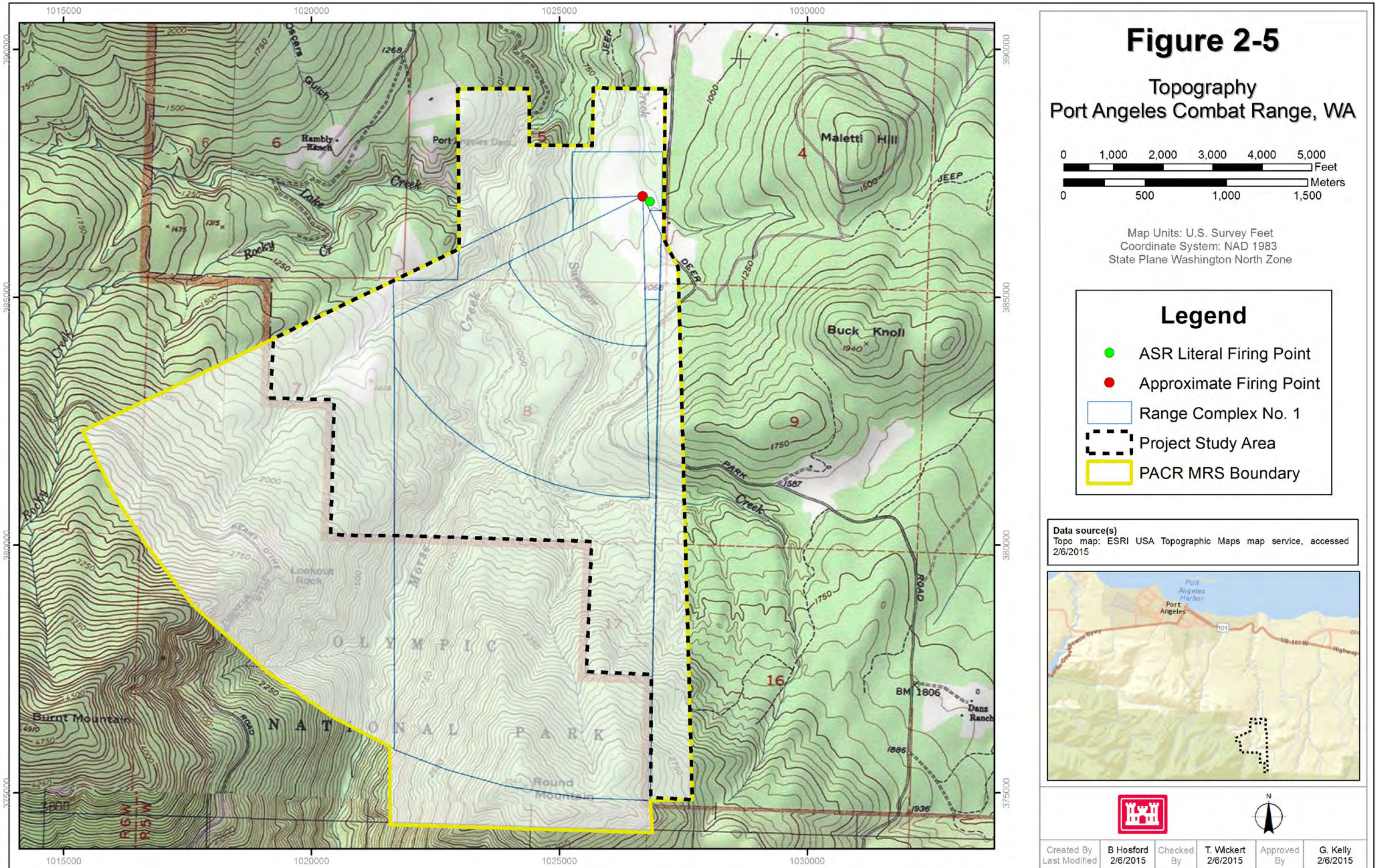
Figure 2-5
Topography
Port Angeles Combat Range, WA
0 1,000 2,000 3,000 4,000 5,000 Feet
0 500 1,000 1,500 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
ASR Literal Firing Point
Approximate Firing Point
Range Complex No. 1
Project Study Area
PACR MRS Boundary
Data source(s)
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Created By Last Modified
B Hosford 2/6/2015
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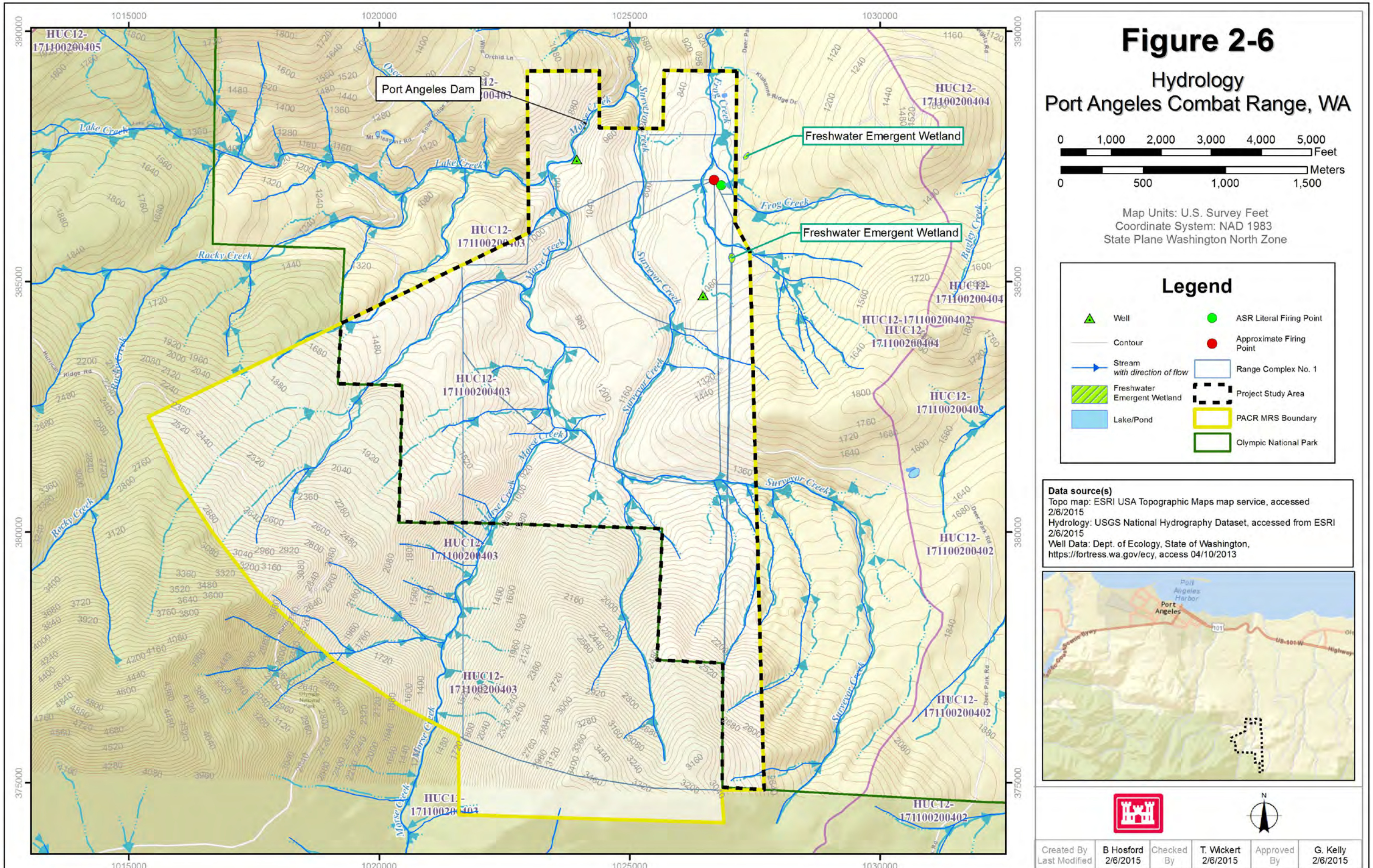
Figure 2-6
Hydrology
Port Angeles Combat Range, WA
0 1,000 2,000 3,000 4,000 5,000 Feet
0 500 1,000 1,500 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
Well
ASR Literal Firing Point
Contour
Approximate Firing Point
Stream with direction of flow
Range Complex No. 1
Freshwater Emergent Wetland
Project Study Area
Lake/Pond
PACR MRS Boundary
Olympic National Park
Data source(s)
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Hydrology: USGS National Hydrography Dataset, accessed from ESRI 2/6/2015
Well Data: Dept. of Ecology, State of Washington, https://fortress.wa.gov/ecy, access 04/10/2013
Port Angeles Dam
Freshwater Emergent Wetland
Freshwater Emergent Wetland
Lake Creek
Rocky Creek
Morse Creek
Surveyor Creek
Frog Creek
Port Angeles Harbor
Port Angeles
HUC12-171100200405
HUC12-171100200404
HUC12-171100200403
HUC12-171100200402
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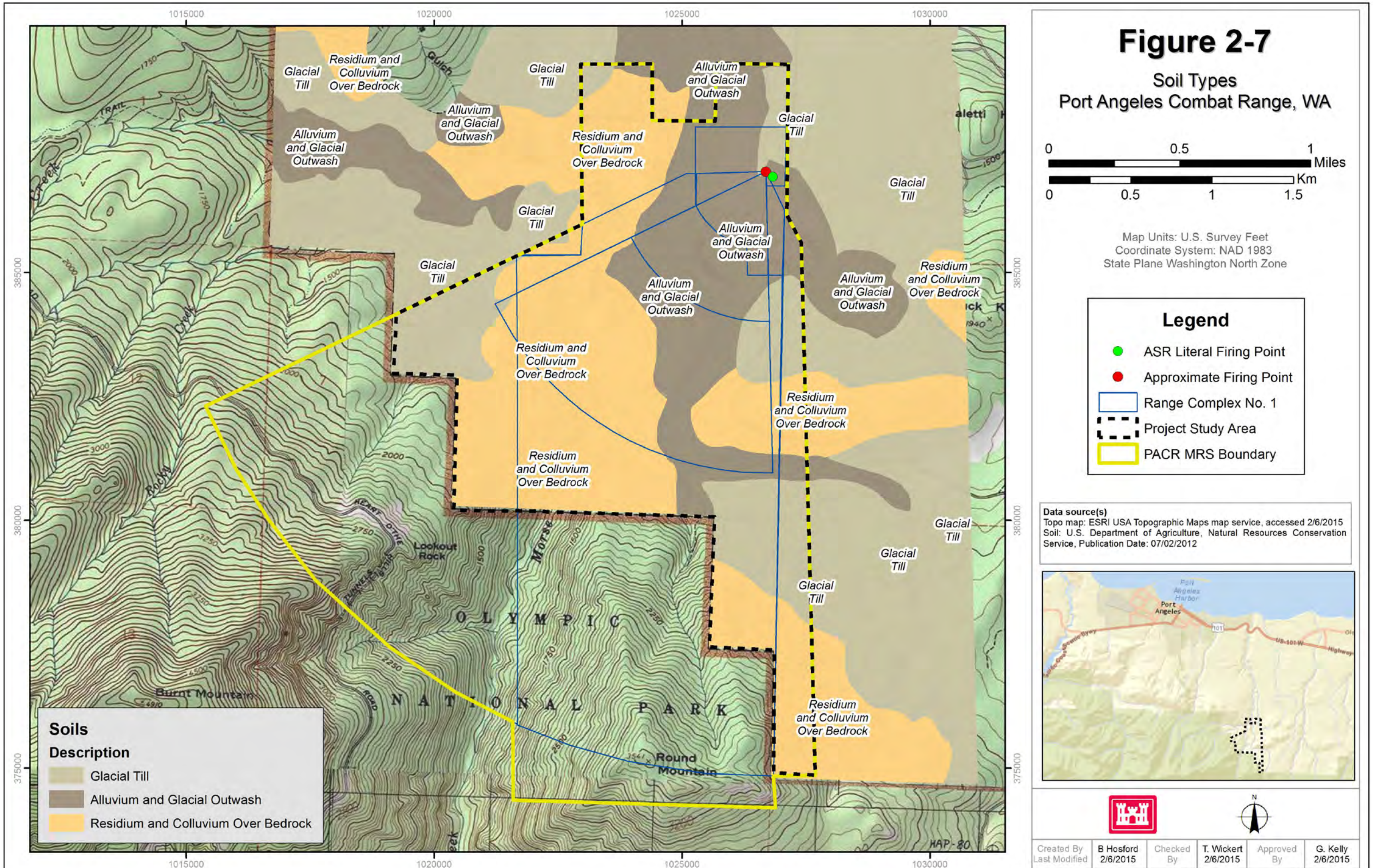
Figure 2-7
Soil Types
Port Angeles Combat Range, WA
0 0.5 1 Miles
0 0.5 1 1.5 Km
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
ASR Literal Firing Point
Approximate Firing Point
Range Complex No. 1
Project Study Area
PACR MRS Boundary
Data source(s)
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Soil: U.S. Department of Agriculture, Natural Resources Conservation Service, Publication Date: 07/02/2012
Soils
Description
Glacial Till
Alluvium and Glacial Outwash
Residium and Colluvium Over Bedrock
Glacial Till
Residium and Colluvium Over Bedrock
Alluvium and Glacial Outwash
OLYMPIC NATIONAL PARK
Lookout Rock
Burnt Mountain
Round Mountain
Port Angeles
Created By Last Modified
B Hosford 2/6/2015
Checked By
T. Wickert 2/6/2015
Approved By
G. Kelly 2/6/2015

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2.2.11 Potential Receptors

2.2.11.1 ECOLOGY

The MRS contains varied habitat that supports a range of wildlife. The USFWS listing (USFWS, 2013a) identifies the following Threatened and Endangered (T&E) species that may be present on or near the MRS:

- Bull Trout (Salvelinus confluentus) – Coastal Puget Sound distinct population segment (DPS) - Threatened
- Marbled Murrelet (Brachyramphus marmoratus) – Threatened
- Northern Spotted Owl (Strix occidentalis caurina) – Threatened
- Short-tailed albatross (Phoebastria albatrus) [outer coast] – Endangered

There is federally designated critical habitat for the following T&E species in Clallam County:

- Bull Trout
- Marbled Murrelet
- Northern Spotted Owl

There is there is no designated critical habitat located on the MRS; however, there is federally designated critical habitat located within one-mile of the MRS. Recovery Plans have been published by the USFWS for the Marbled Murrelet and the Northern Spotted Owl (*http://ecos.fws.gov/tess_public/pub/speciesRecovery.jsp?sort=1*) (USFWS, 2014).

The USFWS also maintains species, which are candidate species and proposed species for listing (USFWS, 2013a). The species that are proposed for listing in the State of Washington and possibly present in Clallam County include:

- White Bluffs bladderpod (Physaria douglasii ssp. tuplashensis) – Proposed Threatened;
- Umtanum Desert buckwheat (Eriogonum codium) – Proposed Threatened
- Taylor's Checkerspot (Euphydryas editha taylori) – Proposed Endangered
- Streaked Horned lark (Eremophila alpestris strigata) – Proposed Threatened
- Olympia pocket gopher (Thomomys mazama pugetensis) – Proposed Threatened
- Roy Prairie pocket gopher (Thomomys mazama glacialis) – Proposed Threatened
- Tenino pocket gopher (Thomomys mazama ssp. tumuli) – Proposed Threatened
- Yelm pocket gopher (Thomomys mazama ssp. yelmensis) – Proposed Threatened
- North American wolverine (Gulo gulo luscus) – Proposed Threatened
- Dolly Varden (Salvelinus malma) – Proposed Similarity of Appearance (Threatened)

Species identified as *candidates* for Federal listing (USFWS, 2013a) which are known or believed to occur in the State of Washington and possibly in Clallam County include:

- Yellow-Billed Cuckoo (Coccyzus americanus)
- Oregon Spotted frog (Rana pretiosa)
- Canada Lynx (Lynx canadensis)
- Whitebark pine (Pinus albicaulis)
- Brush Prairie pocket gopher (Thomomys mazama ssp. douglasii)
- Olympic pocket gopher (Thomomys mazama ssp. melanops)
- Shelton pocket gopher (Thomomys mazama ssp. couchi)

- Tacoma Western pocket gopher (Thomomys mazama tacomensis) (Pacific Region)
- Greater sage-grouse (Centrocercus urophasianus)
- Washington ground squirrel (Urocitellus washingtoni)
- Northern Wormwood (Artemisia borealis var. wormskioldii)

Information pertaining to T&E species was sought as part of the planning process. According to the ASR, "Earlier conversations with the Clallam County Extension Office and the NPS environmental personnel, along with review of Environmental Impact Statements and reports from the Natural Heritage Program, indicated there was no confirmed existence of any endangered plant or animal species within the project site. However, it was noted that complete surveys of the area were not done, and it was likely that at least some of the state threatened or endangered wildlife species would occur in a "transient mode" (USACE, 1996). During the RI, the field investigation teams learned that in the past, adjacent landowners had participated in Northern spotted owl surveys conducted by the Washington Department of Natural Resources.

Priority areas for the Marbled Murrelet in Clallam County are near the MRS (WDFW, 2008). Priority areas for anadromous and resident fish are also nearby (Shaw, 2009). Washington Department of Fish and Wildlife (WDFW) Conservation Division defines priority areas as follows: *"Species are often considered a priority only within known limiting habitats (e.g., breeding areas) or within areas that support a relatively high number of individuals (e.g., regular concentrations)*" (WDFW, 2008). The WDNR indicated that there were no records for rare plants or high quality native ecosystems near the MRS (WDNR, 2008).

USFWS Pacific Region 1 Washington Office, the WDNR, and the WDFW Conservation Division are jointly tasked with enforcing Federal statutes with respect to the Endangered Species Act (ESA). In addition, these agencies designate species within the State of Washington that may need specific and additional protection and habitat conservation.

The WDFW Conservation Division provided a comprehensive Federal and State summary of T&E and candidate species for listing and species of concern at their website (*http://wdfw.wa.gov/conservation/endangered/*) (WDFW, 2012).

2.2.11.2 NATURAL RESOURCES

The MRS contains abundant natural resources. The area contains forests, rangeland, streams, and wetlands. The MRS is primarily maintained as a protected watershed for the City of Port Angeles. Manke Lumber Company manages eight parcels of commercial timberlands within the MRS and the Green Crow Company manages one parcel for timber harvesting. The ONP borders the southern boundary of the MRS.

At the completion of the RI, disturbed areas such as where the on-site portable magazine was staged, the demolition area grid Q-09, and parking areas where vegetation had been removed or damaged was hand-seeded with a native seed mix. Inside Passage Seed and Native Plant Services (http://www.insidepassageseeds.com/) (Inside Passage, 2013) was consulted regarding suitable native plants for the MRS. The native seed mixture presented below was utilized for restoration efforts:

6% *Achillea millefolium* Yarrow
10% *Agrostis exarata,* Pacific bentgrass
12% *Danthonia californica,* California oatgrass
18% *Deschampsia caespitosa,* Tufted Hair-grass or Tussock grass
12% *Elymus glaucus*, Wild rye
20% *Festuca rubra*, red fescue or creeping red fescue
8% *Hordeum brachyantherum*, Meadow barley
10% *Lupinus spp.*, Lupine
4% *Prunella vulgaris*, common self-heal or heal-all
100%

2.2.12 Known Explosive Hazards

PACR was used from 1943 through 1944 to train troops in various types of weapons use. The range was intended to be used for tactical firing problems and short-range known distance firing (200 to 300 yards). The ASR also indicated that there were reports that land mines were used at the PACR. An U.S. Army investigator noted a practice land mine was found.

Previous investigations and clearances conducted within the Range Complex No. 1 MRS have identified MEC and MD items, including 81mm mortars, 75mm projectiles, and 37mm projectiles. The historical activities, documented munitions use, and the MEC and MD findings indicate that there is potential for remaining surface and subsurface MEC, and associated MC contamination in the MRS. This RI/FS was performed to the determine the nature and extent of areas impacted by munitions related activities, as well as determine the risk posed to human health and the environment by MEC and MC contamination with the Range Complex No. 1 MRS.

2.3 Historical Information

The following subsections describe the range mission and history of munitions use, and previous investigations conducted at the PACR.

2.3.1 Installation Mission and Operational History

In early 1943, the U.S. Army requested that land be leased in the area of Port Angeles, WA for use as a ground-to-ground combat range. The range was intended to be used for tactical firing problems and short-range known distance firing (200 to 300 yards). Through leases and use permits, approximately 1,600 acres were obtained within Sections 5, 8, and 17 within Township 29 North, Range 5 West of the Willamette Meridian for use as the PACR. The INPR (USACE, 1993) indicated the range was used for weapons practice with 37mm and 75mm projectiles, 60mm and 81mm mortars, and various small arms.

The ASR also indicated that there were reports that land mines were used at the PACR. An U.S. Army investigator noted a practice land mine had been found. There were no buildings or improvements constructed at the PACR other than a spotting tower. Troops were encamped at the Port Angeles Fair Grounds/Conservation Corps Camp. Records indicate that the range consisted of a single firing line, with firing occurring to the south into the hilly and mountainous terrain. Interviews with former residents of the area and enlisted personnel who used the range indicated that all firing was west of Deer Park Road. Firing occurred directly at stationary and moving targets (targets and tanks pulled across the range using cables). Indirect firing occurred using coordinates. In April and May 1944, the range was declared excess and all leases and permits were canceled.

There is no information to suggest that at the time of closing any attempt was made by the U.S. Army to perform any range clearance prior to returning the range lands to private ownership. In addition, there was no information to indicate that the U.S. Army attempted to notify landowners of the actual use of the former range in terms of potential hazards that could remain.

As a result, two youths were killed in August 1948, when a 37mm shell exploded while they were cutting downed timber within the former range. The 37mm shell was embedded in a log they were sawing. Immediately after the death of the two youths, the U.S. Army initiated the dedudding of the area expected to be impacted. On May 7, 1949, a Certificate of Clearance was issued noting that approximately 775 acres had been cleared of dangerous/explosive material. Subsequent clearances of the PACR occurred in 1952, 1955, 1956, and 1957. Copies of the Certificate of Clearances are included as Appendix E within the ASR (USACE, 1996). It should be noted that there were no standard operating procedures (SOPs) identified that document the level of effort for the clearances; however, the typical procedures for clearances performed circa 1950s do not meet the quality requirements of today’s standards. In addition to the clearances being conducted, at some point in the late 1940s, signs were posted warning the public of dangers from munitions and explosive materials at the site. The information included in the ASR (e.g., Certificate of Clearances) has been analyzed and any spatial information that could be accurately extracted is displayed on **Figure 2-8**.

In 1963, 652 acres were purchased by the U.S. Army to restrict and control access to the property. The 652 acres were retained until 1968 when they were transferred to the City of Port Angeles and to Mr. Raymond Diehl. Records indicated that the quitclaim deed included a “surface use only” and indemnity clause. None of the accumulated evidence summarized in the ASR indicated that chemical warfare materiel (CWM) or chemical agent identification sets (CAIS) were used at the PACR, and based upon the documented site usage, there is no reason to suspect the presence of CWM or CAIS (USACE, 1996).

2.3.2 Summary of Munitions Related Activities

PACR was used from 1943 through 1944 to train troops in various types of weapons use. The range was intended to be used for tactical firing problems and short-range known distance firing (200 to 300 yards). The INPR indicated the range was used for weapons practice with 37mm and 75mm projectiles, 60mm and 81mm mortars, and various small arms (USACE, 1993). The ASR (USACE, 1996) and ASR Supplement (USACE, 2004) indicate that 37mm (target practice, high explosive, and armor piercing), 75mm (practice, high explosive, and white phosphorus [WP] smoke), 60mm mortar (high explosive and practice), and 81mm mortar (high explosive, practice, and WP smoke) were used at the PACR. The ASR also included unverified reports of the use of M9A1 High Explosive Anti Tank (HEAT) rifle grenades, 2.36-inch rockets (practice and HEAT), and anti-personnel and anti-tank practice mines. The quantities of munitions used at the PACR are unknown.

Previous investigations and clearances conducted within the Range Complex No. 1 MRS have identified MEC and MD items, including 81mm mortars, 75mm projectiles, and 37mm projectiles. The historical activities, documented munitions use, and the MEC and MD findings indicate that there is potential for remaining surface and subsurface MEC, and associated MC contamination in the MRS. This RI/FS was performed to the determine the nature and extent of areas impacted by munitions related activities, as well as determine the risk posed to human health and the environment by MEC and MC contamination with the Range Complex No. 1 MRS.

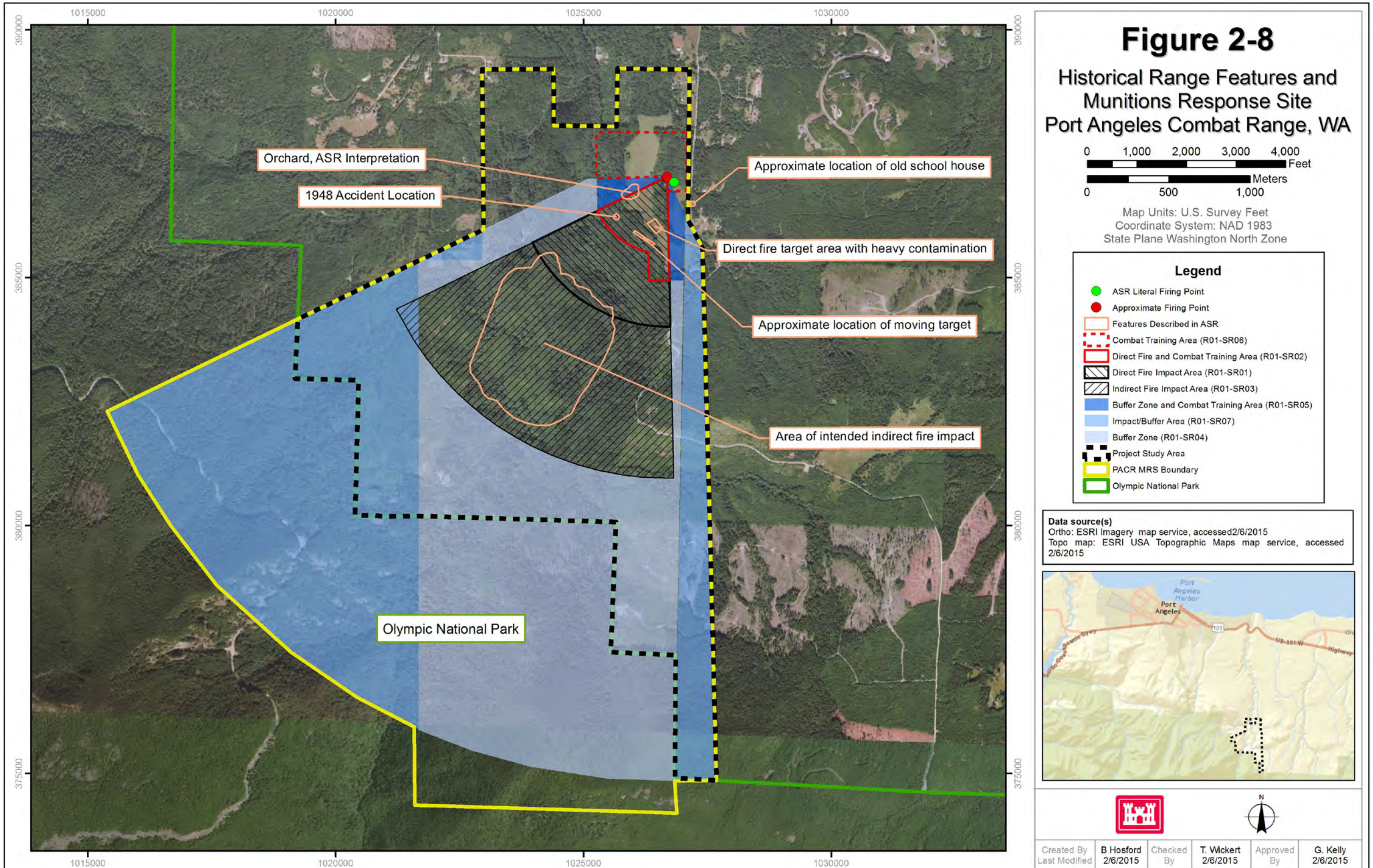
Figure 2-8
Historical Range Features and Munitions Response Site
Port Angeles Combat Range, WA
0 1,000 2,000 3,000 4,000 Feet
0 500 1,000 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
ASR Literal Firing Point
Approximate Firing Point
Features Described in ASR
Combat Training Area (R01-SR06)
Direct Fire and Combat Training Area (R01-SR02)
Direct Fire Impact Area (R01-SR01)
Indirect Fire Impact Area (R01-SR03)
Buffer Zone and Combat Training Area (R01-SR05)
Impact/Buffer Area (R01-SR07)
Buffer Zone (R01-SR04)
Project Study Area
PACR MRS Boundary
Olympic National Park
Data source(s)
Ortho: ESRI Imagery map service, accessed2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Orchard, ASR Interpretation
1948 Accident Location
Approximate location of old school house
Direct fire target area with heavy contamination
Approximate location of moving target
Area of intended indirect fire impact
Olympic National Park
1015000
1020000
1025000
1030000
390000
385000
380000
375000
Port Angeles Harbor
Port Angeles
101
US-101 W
Highway
N
Created By Last Modified
B Hosford 2/6/2015
Checked By
T. Wickert 2/6/2015
Approved By
G. Kelly 2/6/2015

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2.3.3 Documentation and Identification of Munitions-Related Sites at the PACR

Areas potentially impacted by munitions-related activities were identified through a phased investigation process under the MMRP. These areas were investigated and the boundaries refined, and the terminology used to designate these areas changes as they move through the process. The designations of sites or areas under investigation at the PACR were developed as follows:

- Initial areas or ranges where munitions-related activities may have been conducted were identified based on historical records and limited site visits as documented in the ASR (USACE, 1996). Initial boundaries for these ranges were drawn using historical maps, aerial photos, and other documentation as available. Initially the ranges and other areas were designated as Areas of Interest (AOIs) A through F.
- These AOIs, or potentially impacted areas and ranges, were further evaluated in the ASR Supplement (USACE, 2004). The range boundary and sub-ranges were developed considering munitions types, exposure potential, and other considerations from the CSM for each AOI (Shaw, 2009).
- The PACR is designated in the MMRP inventory in the Defense Environmental Program's Annual Report to Congress (ARC), as early as Fiscal Year 2007 (DENIX, 2008). The MMRP inventory was prepared to document the status, progress, and projected costs of environmental restoration programs.
- The SI collected information needed to determine if any areas qualify for NDAI because they pose no significant health threat or explosive hazard, to determine the need for immediate removal action, and to collect data to better characterize the site for more effective initiation of the RI/FS.
- The Range Complex No. 1 Munitions Response Area (MRA) and sub-ranges were further investigated through site walks and sampling during the SI. The MRA was determined to require additional investigation in a RI and was retained as an MRS (Shaw, 2009).

In this report, references to historical ranges and activities are consistent with the designation (AOI, MRA, sub-range, MRS) that was current relative to the information cited and used for evaluation and interpretation of the RI findings.

2.3.4 Identification of Port Angeles Combat Range

The PACR is included in the MMRP Inventory in the Defense Environmental Programs Annual Report to Congress Fiscal Year 2007 (DENIX, 2008) under Federal Facility Identification number WA09799F318400 with range information as identified in **Table 2-1**. As described in **Section 2.3.3**, the ranges at the PACR were initially identified in the ASR (USACE, 1996) as AOIs, and were subsequently consolidated into one range and seven sub-ranges in the ASR Supplement. The acreage and coordinates for Range Complex No. 1 and sub-ranges as listed in the ASR Supplement (USACE, 2004) are identified in **Table 2-3** on the next page.

Table 2-3 ASR Ranges and Sub Ranges – Port Angeles Combat Range – ASR Supplement

ASR Range/Sub-range Name	ASR Range Identification	Approximate Acreage (acres)
Range Complex No. 1	F10WA003301R01	2,629
Direct Fire Impact Area	F10WA003301R01-SR01	119
Direct Fire and Combat Training Area	F10WA003301R01-SR02	37
Indirect Fire Impact Area	F10WA003301R01-SR03	483
Buffer Zone	F10WA003301R01-SR04	856
Buffer Zone and Combat Training Area	F10WA003301R01-SR05	23
Combat Training Area	F10WA003301R01-SR06	41
Impact/Buffer Area	F10WA003301R01-SR07	960

***Note**: The ASR Ranges were identified and compiled in 1996.*

The reported approximate total area of Range Complex No.1 (2,629 acres) exceeds the total area of the seven sub-ranges combined (2,519 acres). This discrepancy is due to the Impact/Buffer Area extending beyond the FUDS property boundary in the northern portion of the Range Complex No. 1 MRS. The project geographic information system (GIS) files depict the actual total acreage of the Range Complex No. 1 as 2,629.8 acres.

2.4 Previous Investigations

Several investigations focusing on the identification of MEC have been performed at the PACR. The following sections describe the scope and major conclusions of previous work.

2.4.1 Identification of Munitions Response Areas

The Range Complex No. 1 MRA was established based on the AOIs identified in the ASR completed in 1996 (USACE, 1996), the ASR Supplement (USACE, 2004), and the SI completed in 2009 (Shaw, 2009). Munitions used, impact areas, and firing points were confirmed at the AOIs during site visits. In many cases, the AOIs had similar current and reasonably anticipated future land uses and thus had the same exposure potential. They also would have the same or very similar investigation and decision-making approaches. Therefore, to facilitate evaluation for future munitions response activities, they were combined into one MRA. The MRA was developed based on three criteria: munitions types, exposure potential, and other notable considerations from the CSM for the AOIs.

2.4.2 Identification of Munitions Response Sites

A SI was completed in 2009 and included Technical Project Planning (TPP) activities involving key stakeholders to identify concerns and develop the plan for further investigation of the MRA (Shaw, 2009). SI activities included additional records research and coordination with the Washington Historical Society, and the Washington Department of Ecology (WDOE), and included review of historical aerial photographs to supplement the information gathered during the ASR (USACE, 1996) and ASR Supplement (USACE, 2004). Field activities were conducted that included visual surveys and sampling to assess potential munitions-related soil, sediment, groundwater, and surface water contamination. The objective of the SI was to determine whether the MRA required additional action by evaluating the presence or absence of MEC or MEC-related MC and to determine the possibility of exposure and impacts to human health or the environment.

Based on evaluation of the SI records research and field results, the PACR MRA was recommended for further investigation, and the MRA was designated as an MRS (**Figure 2-8**).

The Range Complex No. 1 MRS boundary extends beyond the project study area. However, due to the NPS and the DoD not having a programmatic agreement to address MMRP sites the acreage within the ONP was not investigated.

2.4.3 Certificates of Clearance

There have been multiple range clearances on the PACR since World War II (WWII). On May 7, 1949, a Certificate of Clearance was issued noting that approximately 775 acres had been cleared of dangerous/explosive material. Subsequent clearances of the PACR occurred in 1952, 1955, 1956, and 1957. It should be noted that there were no SOPs identified that document the level of effort for the clearances; however, the typical procedures for clearances performed circa 1950s do not meet the quality requirements of today's standards. The clearance reports are available in Appendix E of the ASR (USACE, 1996).

2.4.4 Range Clearance Technology Assessment

In 1986, a Range Clearance Technology Assessment was completed by the Naval Explosives Ordnance Disposal Facility Center (NEODFC) for the PACR. The report is limited to a one-page summary and does not contain details regarding how the conclusions were derived. The report concluded that the future use of the PACR is scenic and livestock grazing; access to virtually all of the range is extremely limited due to terrain and vegetation; high explosive filled munitions have been used on the range; surface and selected subsurface clearance has been accomplished; and additional mechanical clearance of the range is environmentally, technically and economically unfeasible at this time or in the foreseeable future. The report recommended that the PACR not be considered for mechanical clearance in the foreseeable future; an investigation be conducted to determine the effect of natural processes on unexploded munitions; and restrictions placed on the use of the land remain in force (NEODFC, 1986).

2.4.5 Inventory Project Report

An INPR was prepared and issued in 1993 (USACE, 1993). The INPR stated, "Based on the foregoing findings of fact, the site has been determined to be formerly used by the DoD. It is therefore eligible for the Defense Environmental Restoration Program – Formerly Used Defense Sites, established under 10 USC 2701 et seq." (USC, 2004). It was also proposed that further evaluation of the site be completed to better determine the hazards posed by the presence of unexploded ordnance (UXO).

2.4.6 Archives Search Report

The ASR was prepared and issued in 1996 (USACE, 1996) and summarized historical information and information collected during a site visit (July 25-29, 1994) to confirm site conditions. The ASR identified six AOIs:

- Area A – Direct Fire Impact Area
- Area B – Indirect Fire Impact Area
- Area C – Buffer Zone
- Area D – Combat Training Area

- Area E – All remaining land
- Area F – Impact/Buffer Area (additional acreage)

The ASR identified the likely munitions used at the PACR. During the site visit, the ASR team did not observe any ordnance-related items, metal fragments, or obvious signs of ordnance usage. None of the accumulated evidence summarized in the ASR indicated that CWM or CAIS were used at the PACR (USACE, 1996).

2.4.7 Archives Search Report Supplement

The ASR Supplement identified one range and seven sub-ranges as follows (USACE, 2004):

- Range Complex No. 1:
    - Direct Fire Impact Area
    - Direct Fire and Combat Training Area
    - Indirect Fire Impact Area
    - Buffer Zone
    - Buffer Zone and Combat Training
    - Combat Training Area
    - Impact/Buffer Area

2.4.8 Site Inspection

A SI was conducted in 2008 and 2009 for the USACE Northwestern Division Omaha District (NWO) Military Munitions Design Center. The technical approach was based on the *Type 1 Work Plan, SI at Multiple Sites, NWO Region* (Shaw, 2006); and the *FUDS, MMRP, SI, Program Management Plan* (USACE, 2005). Field activities included visual surveys and environmental media sampling (Shaw, 2009).

Visual surface reconnaissance was conducted between October 20 and October 24, 2008, along meandering paths and along roadways through portions of the PACR. A two-person reconnaissance team, including a qualified UXO Technician, conducted the visual inspection.

The team documented conditions with respect to vegetative cover, evidence of military activity, unexpected debris or material, presence or absence of water or any other conditions that could potentially impact planned field activities. Particular attention was paid to identifying MEC and MD, potential indications of contamination such as vegetative stress and other features of interest (e.g., building foundations, permanent structures, etc.). Additionally, the field reconnaissance team recorded the path walked and driven within the MRS using a hand-held global positioning system (GPS) unit. Digital photographs were taken to document significant features and sample points. Representative photographs of reconnaissance and sampling activities and observations are included in the SI Final Report.

The walking visual field reconnaissance was conducted within open fields and accessible abandoned logging roads within the Buffer Zone and Combat Training Area (SR-05), the Combat Training Area (SR-06), the Direct Fire and Combat Training Area (SR-02), and the Indirect Fire Impact Area (SR-03). Vehicle reconnaissance was used to supplement the walking reconnaissance and focused on observing for indications of former military operations. The walked visual reconnaissance path length was approximately 11.2 miles. The vehicle reconnaissance path length was approximately 40.7 miles. Traversing within areas where no logging roads were present was prevented due to steep slopes near creek bottoms, dense vegetation, and fallen timber that made travel unsafe. Portions of the Combat Training Area (SR-06), Direct Fire and Combat Training Area (SR-02), and Direct Fire Impact Area (SR-01) sub-ranges were comprised of open meadows with thick, tall (up to knee high) grass that were used for cattle grazing. An open meadow can be seen on **Figure 2-8** as a lighter green with a sharp boundary within the forested areas, which is where the direct fire target area, with heavy contamination and the orchard based on the ASR interpretation, is located. The tall grass restricted visual observations in the open meadows. In the extreme northern portion of this open meadow, old farm equipment, car bodies, and miscellaneous debris were observed. No media sampling was completed in this extreme northern area.

No obvious military use features were observed in the open meadow or in the surrounding heavily forested areas. All other areas in the PACR were very heavily forested with thick underbrush and fallen timber. Access through some of the heavily forested areas was via old logging roads. Travel beyond these old logging roads was very limited because of the thick vegetation and fallen timber. No obvious sign of military training activities was observed during the visual reconnaissance. The area east of Surveyor Creek was inaccessible because of the terrain and vegetation hazards. Logged areas observed on aerial photographs were heavily overgrown by thick underbrush and alder trees and safe foot access was not possible.

During the SI field reconnaissance, anomaly avoidance was implemented using a magnetometer to identify subsurface anomalies. Subsurface anomalies identified during the SI were noted in the area described in the 1955 range clearance documents (refer to **Section 2.4.3**) as an “Area of Heavy Contamination”, which is also in the general vicinity of the1948 Accident Location. No MEC or MD or obvious signs of military activity were identified during SI field reconnaissance activities completed in October 2008, (Shaw, 2009).

The SI collected surface soil, sediment, surface water, and groundwater samples that were analyzed for metals of concern (chromium, copper, iron, lead, mercury, and nickel) and aluminum, magnesium, manganese, and zinc by United States Environmental Protection Agency (USEPA) SW-846 Methods 6020 and 7470/7471 and explosives (including nitroglycerin and Pentaerythritol tetranitrate [PETN]) by USEPA Method 8330 Modified (USEPA, 2006).

Because MC concentrations were below agreed upon screening values, the stakeholders agreed that MC sampling would not be required for subsequent investigations (Shaw, 2009).

Based on historical evidence of MEC, Range Complex No. 1 at the PACR FUDS was recommended for additional investigation for potential MEC hazards. Based on the SI, the location and size of the MRS at the PACR were correct as provided in the MMRP Inventory (Shaw, 2009).

2.4.9 Environmental Security Technology Certification Program Demonstration

In 2011, digital geophysical mapping (DGM) data were collected over an area at the PACR (portions of SR-01 and SR-05) in an effort to characterize the site for future Environmental Security Technology Certification Program (ESTCP) demonstrations. Naeva Geophysics, Inc. under a subcontract to Hydro Geologic, Inc. (HGL) who was supporting the ESTCP, collected data on a parcel of approximately 31 acres using a Geonics EM61 MK-2, with a series of parallel transects spaced 30 meters apart. **Figure 2-9** shows the areal extent of the data coverage using the EM61-MK2 (ESTCP, 2011).

On September 29, 2011, HGL's UXO technician found a 37mm projectile at the southern extent of transect T-4 (**Figure 2-9**). The North American Datum of 1983 (NAD83) Washington State Plane coordinates in U.S. survey feet were 386308.69 northing and 1026013.62 easting. The UXO technician immediately notified the Clallam County Sheriff's office. A Washington State Police bomb technician safely disposed of the item explosively on September 29, 2011 (ESTCP, 2011).

The ESTCP DGM data was interpreted in May 2013 (**Figure 2-9**). Density analysis of the ESTCP dataset was performed using a weighted kernel density estimation (KDE) analysis utilizing the ESRI Spatial Analyst toolbox. This process is commonly used to generate a probability density function for point datasets. An initial KDE raster was generated over the entire ESTCP survey area utilizing the anomaly picks from the study. The initial KDE raster was weighted to account for coverage bias to accommodate for the approximate 3.5% coverage of the site by DGM survey transects. Percent coverage was determined for each one-meter kernel location in the KDE by creating a regularly spaced dense grid of points. These points were selected and retained where they intersected the actual transect swath from the survey. A KDE was then performed on the selected points and the output was normalized to values between 0 (no coverage) and 1 (100% coverage). This value was then applied to the original density calculation to provide final estimates of actual target densities throughout the ESTCP study area.

2.4.10 Cultural Resources Survey

No cultural resources have been identified within the PACR. During the SI, The Washington Department of Archaeology and Historic Preservation (WDAHP) was contacted to determine if any new historical or cultural sites may have been identified within the PACR. The WDAHP recommended that consultation with nearby tribes and an archaeological survey be conducted (WDAHP, 2008). The USACE Seattle District completed an archaeological evaluation of the PACR and noted a "No Historic Properties Affected" determination. This determination was forwarded to the WDAHP, who concurred with the determination. A copy of the WDAHP concurrence letter is included in the SI Report (Shaw, 2009). No further consultation with the WDAHP was planned. The RI did not encounter items with potential cultural or archeological relevance.

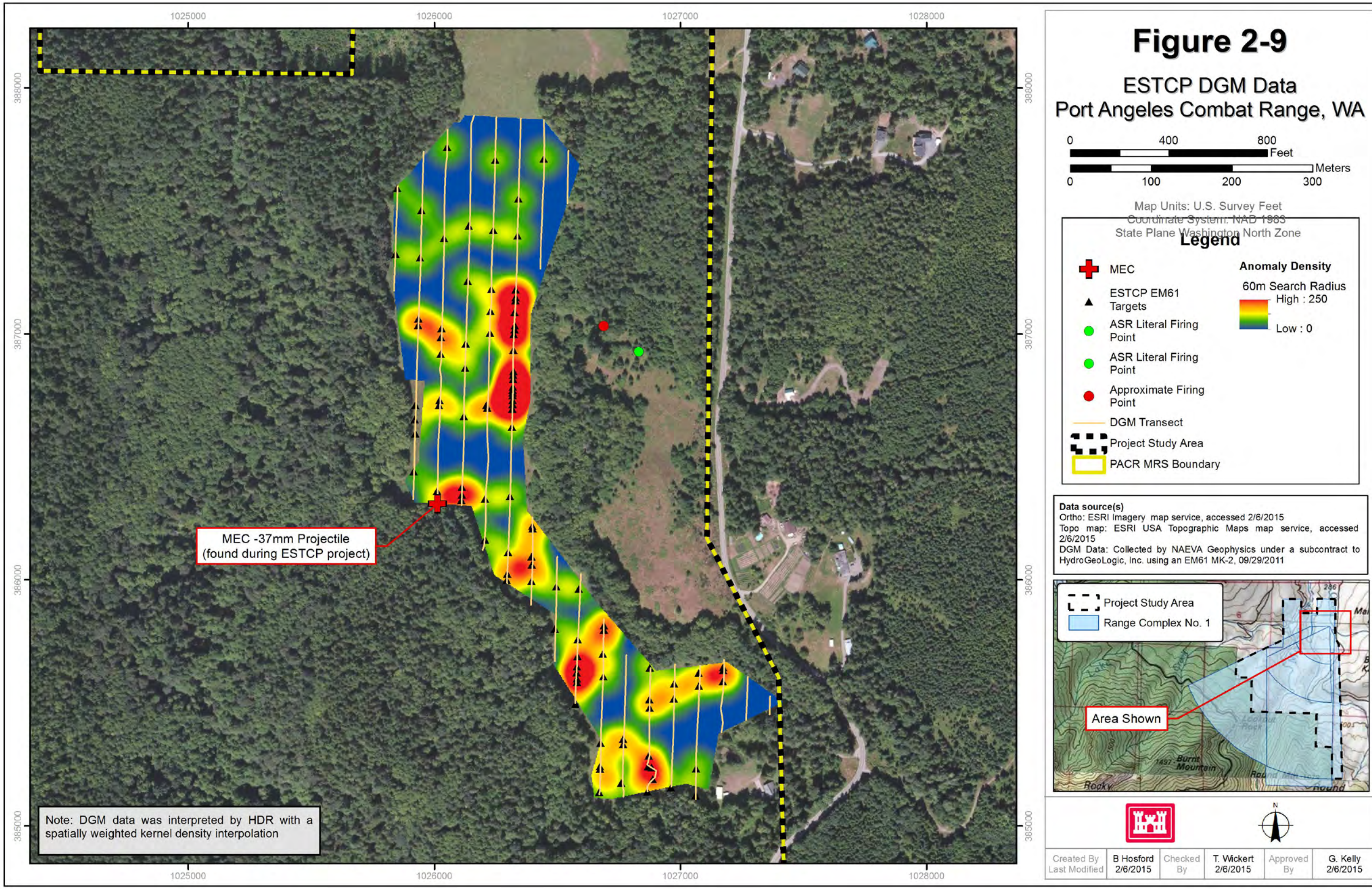
Figure 2-9
ESTCP DGM Data
Port Angeles Combat Range, WA
0 400 800 Feet
0 100 200 300 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
MEC
ESTCP EM61 Targets
ASR Literal Firing Point
ASR Literal Firing Point
Approximate Firing Point
DGM Transect
Project Study Area
PACR MRS Boundary
Anomaly Density
60m Search Radius
High : 250
Low : 0
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
DGM Data: Collected by NAEVA Geophysics under a subcontract to HydroGeoLogic, Inc. using an EM61 MK-2, 09/29/2011
Project Study Area
Range Complex No. 1
Area Shown
MEC -37mm Projectile
(found during ESTCP project)
Note: DGM data was interpreted by HDR with a spatially weighted kernel density interpolation
1025000
1026000
1027000
1028000
388000
387000
386000
385000
Created By Last Modified
B Hosford 2/6/2015
Checked By
T. Wickert 2/6/2015
Approved By
G. Kelly 2/6/2015

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3.0 Project Remedial Response Objectives

The remedial response objective for sites where MEC may be present is to reduce explosive safety hazards and MC, and to ensure protection of human health and the environment. An additional objective for the Range Complex No. 1 MRS is to ensure that access to the public lands is maintained, and the current and future use of the site is not limited. This RI/FS was conducted to collect data needed to complete characterization of the MRS, to determine the nature and extent of MEC and MC, and to determine whether additional action is required under the MMRP and CERCLA to achieve these objectives. The data are evaluated and presented in this report along with analysis of the possible actions that may be taken at the site.

3.1 Conceptual Site Model and Project Approach

3.1.1 Conceptual Site Model

Site-specific CSMs for human and ecological receptors were developed to address the existing or potential access and exposure pathways for MEC and/or MC at the MRS Range Complex No. 1. The CSMs were developed and presented in the *RI Work Plan* (HDR, 2013) and have since been revised based on the results from the RI field effort.

The PACR CSMs represent descriptions of the site and the environment based on existing knowledge. They describe contamination sources and possible receptors, and the interactions that link them. They are intended to assist in planning, data interpretation, and communication. The CSMs address both current and future land use scenarios. The CSMs are developed and used as planning tools to integrate information from a variety of resources and to evaluate the information with respect to project objectives and data needs. As such, CSM development is an iterative process based on further knowledge acquisition, field activities, and interim remedial actions. The information provided is then used to refine the CSMs as necessary through the RI/FS process.

Current and future land uses were described in **Section 2.2.3**. The City of Port Angeles lands within and adjacent to the MRS are actively managed for watershed protection. There are private parcels including primary residences within and adjacent to the MRS. Additional development should be anticipated on these privately owned parcels. The Manke Timber Corporation manages timber harvesting on their property within the MRS (parcel numbers 47418, 47483, 47485, 47492, 47493, 47495, 47497, and 47505). Green Crow Corporation also manages timber on parcel 47498 (**Figure 2-3**). There is no designated critical habitat located on the PACR; however, there is abundant wildlife on and adjacent to the site, and critical habitat for federally listed T&E species within one mile of the PACR. No planned changes in the existing land uses are known at this time.

These land uses and the human and ecological receptors associated with them are reflected in the CSMs, and this information was a primary consideration in developing the project approach for investigation and evaluation of potential remedial actions.

The Range Complex No. 1 MRS represents a very large area with terrestrial and aquatic features and multiple ecological receptors; additional information was needed to adequately characterize this MRS. Without detailed range-specific information at hand, when the RI commenced, all potential soil, sediment, and surface water exposure pathways were considered in the development of the RI Work Plan (HDR, 2013). This included the potential for complete groundwater pathways. The presence or absence of groundwater, especially via seeps and springs was unknown. Consequently, as a conservative measure, protection of groundwater was also evaluated.

For the SI (Shaw, 2009), a text-based CSM was developed for the Range Complex No. 1 MRS as a whole based on the review of historical information and the ASR (USACE, 2004). The graphical CSMs presented in the RI Work Plan (HDR, 2013) were updated following completion of the RI activities and are presented in **Section 5.0** of this report.

The environmental sampling data from the SI (Shaw, 2009) were reviewed for establishing an initial list of potential concern (COPCs) or contaminants of potential ecological concern (COPECs) for the RI. There were no COPCs or COPECs identified for further evaluation in the RI.

3.1.1.1 SITE INFORMATION AND LAND USE

The current primary land uses for the MRS is logging, infrastructure maintenance (e.g., Morse Creek Dam), recreational activities, hunting, and private residential use. Most of the PACR is privately owned. There are no known mining claims in the MRSs. No planned changes in the existing land uses are known at this time.

These land uses and the human and ecological receptors associated with them are reflected in the CSMs, and this information was a primary consideration in developing the project approach for investigation and evaluation of potential remedial actions.

3.1.1.2 POTENTIAL MEC EXPOSURE TO HUMAN AND ECOLOGICAL RECEPTORS

The potential for MEC (i.e., sources of MEC) resulted from the historical munitions use in the PACR during the WWII period. This area was used as a combat range for military maneuvers and target practice, which included firing points and moving targets (targets and tanks pulled across the range using cables)

Based upon the discovery of five MEC items in surface soil during the RI (**Figure 5-10**), the potential for access and contact with MEC exists at the MRS Range Complex No. 1 for all mobile receptors. In addition, MEC on the subsurface could potentially be accessed by all mobile receptors conducting intrusive activities. Considerable MD were recovered down to 1.5 feet bgs. Numerous removal actions and surface sweeps have been conducted since WWII, and the majority of MEC items have been removed from the surface.

Access to the MRS, Range Complex No. 1 is generally unrestricted, except uneven and sometimes steep terrain, dense vegetation, and dilapidated fencing can limit mobility. Public access may be limited on private property. Access to visible MEC on the surface is still of concern even with previous investigations and removals as the MEC items recovered during this RI were in surface soil. Human receptors conducting intrusive activities could potentially contact MEC in surface and subsurface soils except in cliff areas and other steep or inaccessible terrain.

Human receptors could be exposed to MEC in surface and subsurface soils through the following pathways:

- Physical disturbance
- Intrusive activities
- Handle or tread underfoot

It is possible that MEC could have migrated down the slopes from its original positions due to heavy precipitation; however, human access to potential MEC on the steeper slopes to the west of MRS Range Complex No. 1 is likely limited.

3.1.1.3 POTENTIAL MC EXPOSURE FOR HUMAN AND ECOLOGICAL RECEPTORS

The updated CSMs consider that MEC and MC on the surface and subsurface could be potentially accessed by all mobile receptors due to the unrestricted access within the MRS. MC released to the environment from damaged or leaking munitions could become COPCs for human receptors, and COPECs for ecological receptors. As such, the chemicals could potentially present hazards to all receptors from several exposure pathways.

Human receptors could be exposed to MC contamination in surface and subsurface soils through the following pathways:

- Incidental soil ingestion.
- Dermal contact with soil.
- Fugitive dust inhalation primarily from surface soil; likely insignificant exposure pathway due to heavy vegetative cover and high rates of annual precipitation.
- All exposures would be assumed to take place outdoors.

Ecological receptors could be exposed as follows:

- Plants – direct soil contact and root uptake; root uptake not addressed quantitatively.
- Soil Invertebrates (soil fauna) – direct soil contact, soil ingestion; soil ingestion not addressed quantitatively.
- Animals – incidental soil ingestion, dermal soil contact, dust inhalation, and dietary uptake of potentially contaminated food items. Neither dermal contact nor inhalation of fugitive dust can be assessed quantitatively due to the lack of receptor-specific exposure factors.
- Aquatic Life – incidental sediment and surface water ingestion and direct contact, and dietary uptake of food items. Dermal contact cannot be assessed quantitatively due to the lack of receptor-specific exposure factors.

3.1.2 Project Approach

This RI collected the data necessary to support decision-making regarding the potential explosive hazard posed by MEC and potential risk posed to human health and the environment by MC directly attributable to MEC. A combination of investigation methods were used to optimize data collection. Unsurveyable areas consisted of slopes greater than 65%, heavy vegetation that could not be cleared with hand tools, water bodies that could not be traversed by foot, and any other field conditions that presented an unacceptable safety risk to the field investigation team.

The project area was delineated into three separate technical approach areas based on the types of munitions used, how the munitions were fired, the types of investigation methods required to delineate nature and extent and the ability to implement the technology available at the time of the RI based on site-specific limitations such as topography and vegetation. The three different technical approach areas are presented below:

Technical Approach 1 was conducted within the Combat Training Area and buffer zones north of the Firing Point (R01-SR06). The technical approach within this area was driven by the potential use of small arms and practice land mines.

- AVS with real time excavations by hand were performed by a UXO Technician and a Geophysical/Field Technician to characterize the nature and extent of MEC and small arms (i.e. visual evidence of military small arms such as brass casings or lead projectiles). All field teams were assembled in accordance with EM-385-1-97 (USACE, 2013). If real time digs were performed, the Geophysical/Field Technician was temporarily replaced with a UXO Technician. Initial AVS transects were spaced 150 feet apart.
- In-situ XRF screening was conducted to analyze for lead in soils where natural features (e.g., natural berm feature) or small arms debris was identified. XRF screening was utilized for information only and to assist the field investigation team to determine sampling locations for subsequent laboratory analysis (if it was required).
- Sampling for laboratory analysis would have been conducted if there was evidence of small arms use and elevated XRF lead levels above the WDOE soil clean-up level of 250 mg/kg. Environmental media samples for laboratory analysis would have been collected as necessary for all decision-making purposes.

Technical Approach 2 was conducted within the Direct Impact Fire Area and adjacent buffer zones to the east and west (R01-SR01, R01-SR02, R01-SR05, a portion of R01-SR04, and a portion of R01-SR07). The technical approach within this area was driven by the use of 37mm and 75mm artillery fired at fixed and towed ground based targets within a discrete area.

- AVS was performed by a UXO Technician and a Geophysical/Field Technician. All field teams were assembled in accordance with EM-385-1-97 (USACE, 2013). Initial AVS transects were spaced 75 feet apart. AVS transects were spaced 35 feet apart within the open area where there were likely targets (meadow/open area) illustrated in historical aerial photography. Non-munitions related features (e.g., fencing, utilities) that could interfere with DGM were recorded.
- DGM surveys were conducted to determine areas with high subsurface metallic anomaly densities. DGM transects were spaced 75 feet apart. DGM transects were spaced 35 feet apart within the open area where there were likely targets (meadow/open area) illustrated in historical aerial photography.
- 200-foot x 200-foot subsurface investigation grids were positioned over areas identified as containing high anomaly densities (250 anomalies per acre or greater) determined by the DGM. A minimum of 10% of each grid (i.e., a 200 feet x 200 feet grid with 5-foot lanes at the 0-foot, 50-foot, 100-foot, 150-foot and 200-foot intervals) were intrusively investigated. Contiguous subsurface investigation grids stepping out from the high anomaly density areas (i.e., 250 anomalies per acre or greater) were established if munitions were observed and until the extent of the munitions were determined.
- Analytical sampling for explosives would have been conducted, if required.

Technical Approach 3 was conducted within the Indirect Impact Fire Area and adjacent buffer zones to the east, west, and south (R01-SR03, a portion of R01-SR07, and a portion of R01-SR04). The technical approach within this area was driven by the trajectory, distance, and impact of 60mm and 81mm mortars, and the areas identified during the ASR. Some 37mm and 75mm artillery were also anticipated based on the line of sight analysis presented in the approved work plan. Artillery that may have been fired over the intended target within the area presented for Technical Approach 2 could potentially be deposited within the area defined by Technical Approach 3. The topography and vegetation was rugged throughout the area limiting the effective use of DGM and subsurface investigation grids.

- AVS with real time excavations of all anomalies was performed by two UXO Technicians to characterize the nature and extent of MEC. All field teams were assembled in accordance with EM-385-1-97 (USACE, 2013). AVS transects were spaced 75 feet apart within the intended impact area per the ASR and the immediately adjacent 300 feet buffer area. AVS transects were spaced 150 feet apart outside the 300 feet buffer area.
- Analytical sampling for explosives would have been conducted, if required.

3.2 Preliminary Remediation Goals

The Preliminary Remediation Goals (PRGs) are used to determine the need for and effectiveness of remedial actions to address MC contamination. There are no established PRGs for MEC, particularly UXO and Discarded Military Munitions (DMM); therefore, the property's use and MEC exposure pathways drive the development of the munitions response alternatives. In general, remediation goals for MEC focus on removing or limiting the exposure pathways.

For MC, the PRGs are established screening levels. The USEPA has developed Risk Screening Levels (RSLs) (USEPA, 2013) for residential and industrial receptors to differentiate areas that do not require further evaluation from contaminated sites that require further evaluation, including a complete baseline risk assessment. The RSLs are located at USEPA's website "Regional Screening Levels for Chemical Contaminants at Superfund Sites", available at http://www.epa.gov/region9/superfund/prg/ (USEPA, 2013).

3.3 Preliminary Identification of Applicable or Relevant and Appropriate Requirements and "To Be Considered" Information

Section 121 of CERCLA requires that site cleanups comply with federal Applicable or Relevant and Appropriate Requirements (ARARs), or State ARARs in cases where these requirements are more stringent than federal requirements. Applicable requirements are defined as those cleanup or control standards, or other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state laws. Applicable requirements are identified on a site-specific basis by determination of whether the jurisdictional prerequisites of a requirement fully address the circumstances at the site of the proposed remedial activity. A requirement is applicable if the specific terms (or jurisdictional prerequisites) of the statute or regulation directly address the circumstances at the site.

If not applicable, a requirement may be relevant and appropriate if circumstances at the site are sufficiently similar to the problems or situations regulated by the requirement. "Relevant and Appropriate" refers to those cleanup standards, or other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law, that, while not necessarily applicable, address problems or situations sufficiently similar to those encountered at the CERCLA site, and whose use is well suited to the particular site (USEPA, 1988).

ARARs that govern actions at CERCLA sites fall into three broad categories based upon: 1) the munitions-related chemical contaminants present, 2) site characteristics, and 3) alternatives proposed for cleanup. These three categories are identified as chemical-specific, location-specific, and action-specific ARARs. An analysis of Federal ARARs is presented in **Table 3-1** based on the RI data. In accordance with 40 C.F.R. § 300.515(d)(1) (USEPA, 2011), a request was provided to the WDOE for identification of potential State ARARs. WDOE did not provide State ARARs for consideration.

In addition to ARARs, non-promulgated advisories or guidance referred to as "to be considered" (TBC) may also apply to the conditions found at a site. TBCs are not legally binding. The USEPA RSLs are TBCs used for comparison with MC results for the PACR RI/FS.

Table 3-1 Preliminary ARARs, Range Complex No. 1 MRS, Port Angeles Combat Range, WA

Standard, Requirement, Criteria or Limitation	Citations	Description	ARAR Type	Applicability to Site
Endangered Species Act	Endangered Species Act, 16 USC § 1538(a)(1)(B)	Prohibits the unlawful taking of any endangered species.	Location	Applicable to any action that could impact listed or proposed threatened or endangered species at the site.
Migratory Bird Treaty Act	Migratory Bird Treaty Act, 16 USC § 703(a)	Prohibits the unlawful taking, killing or possession of migratory birds.	Location	Applicable to any action that could impact migratory birds present at the site.
Protection of Bald and Golden Eagles	Bald and Golden Eagle Protection Act, 16 USC § 668(a)	Prohibits the unlawful taking of bald and golden eagles, including their parts, nests, or eggs.	Location	Applicable to any action that could impact bald and golden eagles present at the site.

3.4 Summary of Institutional Analysis

An Institutional Analysis is conducted to identify and analyze the institutional framework necessary to support the development of institutional controls (ICs). The purpose of this analysis is to gather background information and document which stakeholder entities have jurisdiction over the Range Complex No. 1 MRS and to assess the capability and willingness of these entities to assert and maintain institutional controls selected as an effective alternative.

With the exception of the private parcels, the MRS is managed for watershed and forest resource management and other activities as described in **Section 2.2.3**.

The stakeholder team includes federal, state, and local agencies and has developed a strong working relationship over the years of examining and addressing historical military munitions in the PACR area. The stakeholders and their jurisdictions for the MRS are:

- USACE, Kansas City District, is responsible for overall project management, with overall management, contractual, and funding responsibility. The USACE conducts the environmental cleanup work on former military land under the FUDS program.
- The City of Port Angeles manages public lands within the MRS.
- Washington Department of Ecology is the lead regulatory agency and provides the State of Washington input and regulatory oversight for the investigation and remediation activities.
- The USEPA is the federal regulatory agency providing oversight for the investigation and remediation activities.
- Area stakeholders are non-agency entities that have an interest in activities occurring in the PACR area. These entities include public and elected officials of surrounding towns, counties, and the state; area residents and landowners; area users such as seasonal, recreational, and special-use permittees; utilities; and emergency responders.

Additionally, the Washington State Police will perform MEC responses for items found by the public as needed after completion of selected remedial alternatives.

The preliminary Institutional Analysis will be refined during a working group session between the USACE and other project stakeholders as part of the development of the Proposed Plan (PP). Additional stakeholder and public input will be considered as part of the formal public comment period. Once the preferred remedial alternative is identified and if it includes the use of Institutional Controls a more detailed Institutional Analysis will be performed including review by the land manager attorney and the USACE general counsel to examine state and local laws relevant to the ICs being considered. The results of the Institutional Analysis including the roles and responsibilities of the stakeholders will be documented within the Decision Document (DD).

Prior to the preparation of the final DD a Memorandum of Agreement (MOA) or a Memorandum of Understanding (MOU) may be prepared to facilitate discussions between the USACE and any land owners or managers that may be affected by the implementation of Institutional Controls. Initial discussions regarding the use of a MOA or MOU would occur during the TPP process.

3.5 Data Needs and Data Quality Objectives

The PACR RI activities included AVS, DGM surveys, in-situ XRF screening for lead in soil, and subsurface investigations. The subsurface investigations were conducted to explore potential subsurface MEC based on the AVS and DGM results.

Data quality objectives (DQOs) were developed for MEC and MC for the PACR RI and followed the *Data Quality Objectives Process for Hazardous Waste Site Investigations, EPA QA/G-4HW* (USEPA, 2000). The DQO process included the following steps:

- State the problem
- Identify the decision
- Identify inputs to the decision
- Define the study boundaries
- Develop a decision rule
- Specify limits on decision error
- Optimize the design for obtaining data

The DQOs for MC sampling were developed in accordance with the systematic planning process in Worksheet #11 of the *Uniform Federal Policy (UFP) Quality Assurance Project Plan (QAPP)* (see Appendix D of the PACR RI Work Plan) (HDR, 2013). **Table 3-2** presents the DQOs established for the Range Complex No. 1 MRS as presented in the RI Work Plan (HDR, 2013). The DQOs for the DGM Geophysical Investigation are provided in **Section 4.1.3** (**Table 4-1**).

Table 3-2 Data Quality Objectives for the Range Complex No. 1 MRS

Step	Data Quality Objective
1. State the problem	There is the potential for surface and subsurface MEC and MC at the PACR MRS based on past military use of the area. The distribution of potential MEC/MD and MC must be established in order to assess the potential explosive hazard associated with MEC, and the potential risk posed to human health and the environment associated with MC contamination. The potential for remaining MEC and MC was identified based on the INPR, the ASR, the ASR Supplement, and SI results (**Section 2.4**). These information sources documented the U.S. Army's use of the PACR for training in tactical firing problems and short-range known-distance firing in 1943 and 1944. Munitions used at the site included 37mm and 75mm projectiles and 60mm and 81mm mortars. There are also unconfirmed reports of small arms, rifle grenade and land mine usage within the MRS.
2. Identify the goal of the study	The soil sampling conducted as part of the SI in 2009 reported no MC concentrations above the agreed upon screening levels and concluded that further MC sampling was not recommended. During the SI, subsurface soils were not addressed. This RI will collect the data necessary to support decision-making regarding the potential explosive hazard posed by MEC and potential risk posed to human health and the environment by MC directly attributable to MEC requiring further action under CERCLA. The RI will evaluate nature and extent of MEC/MD. The RI will identify and characterize any observed MEC/MD source or sources. The extent of the MEC/MD will be characterized horizontally and vertically. The RI will also evaluate the nature and extent of MC in soil from explosives and small arms sources (if warranted). Evaluating the MC extent will include comparing analytical sample results to human health screening levels of MC (**Section 7.1**). The horizontal extent and vertical depth of MC which exceed human health risk-based screening levels will be delineated.

Table 3-2 Data Quality Objectives for the Range Complex No. 1 MRS (Continued)

Step	Data Quality Objective
3. Identify the information inputs	Information inputs are needed to assess the potential hazard posed by MEC and potential risk posed to human health and/or the environment by MC at the MRS. Information inputs in support of decision making will include the compilation of all previously gathered site information, such as the following: • INPR, ASR, and SI Reports (Refer to **Section 2.4**) • Preliminary Conceptual Site Model from the SI • Data to characterize the extent of surface and/or subsurface MEC/MD from metal detector AVS with the hand excavation of identified anomalies throughout the MRS • DGM surveys using an EM61 in selected areas within the MRS to determine areas of high density anomalies o High density anomaly areas (target features/impact areas which generally consist of areas containing 250 anomalies per acre or greater) to be investigated will be selected by the project geophysicist and approved by the USACE. UXO teams will investigate the high density areas to evaluate the subsurface (**Section 4.1.4**). o Refer to **Section 4.2.1** for discussion regarding sampling for lead as an indicator for small arms MC. • Intrusive Investigations (**Section 4.1.4**). o UXO teams will investigate areas containing high anomaly densities (generally 250 anomalies per acre or greater) determined from the DGM data utilizing grid methodology. o Grids will be expanded as necessary to define the horizontal extents of MEC/MD. • Analytical results of discrete samples collected for explosives and lead will be used to determine the nature and extent of potential MC contamination based on MEC discoveries or evidence of small arms activities. MC in soil will only be sampled if the criteria presented in **Section 4.2.1** and **Figure 4-7** is met. • Discrete MC (explosives) soil samples are proposed beneath all MEC items defined by the criteria presented in and discussed in **Section 4.2.1**.
4. Define the study boundaries	The physical boundary of the 2,629* acre Range Complex No. 1 MRS was defined at the conclusion of the SI, though the spatial boundary of this RI will be constrained to those areas within the 1,392 acre FUDS eligible property where ROE may be obtained and AVS, geophysical survey, intrusive investigation and MC sampling data collection may occur. Surveys are not planned in areas where an ROE cannot be obtained. Total acreage investigated will be affected by which ROEs can be obtained and unsurveyable areas (e.g., steep slopes greater than 65%). RI activities are not planned within the ONP because an agreement is not in place between the NPS and DoD to permit environmental investigations. The temporal boundaries of this RI include any limitations of technology in unsurveyable areas. Data acquisition may be limited by unsurveyable areas. *Approximate ASR/SI acreage was 2,629. Project GIS boundary provided by USACE is 2,629.8.

Table 3-2 Data Quality Objectives for the Range Complex No. 1 MRS (Continued)

Step	Data Quality Objective
5. Develop the analytical approach	The purpose of these analyses is to delineate the area considered most likely contaminated with MC. 1. GIS Analysis • Line-of Sight Analysis for artillery (37mm and 75mm projectiles) travel. • Trajectory and effective range for mortars (60mm and 81mm) • Historic Aerial Photography Analysis 2. Assisted Visual Surveys • UXO teams will assess the nature and extent of any MEC/MD located on the surface. • UXO teams will investigate subsurface anomalies indicative of munitions observed during the AVS throughout Technical Approach Areas 1 and 3 to define the nature and extent of subsurface MEC/MD. 3. Digital Geophysical Mapping • DGM is proposed for the Direct Fire Impact Area to identify areas of high anomaly densities. • High density anomaly areas (target features/impact areas which generally consist of an area containing 250 anomalies or greater per acre) to be investigated will be selected by the project geophysicist and approved by the USACE. • UXO teams will reconcile the subsurface anomalies identified by the DGM as target features or as non-munitions related features starting at the high density anomaly areas (250 anomalies per acre or greater) to define the nature and extent of subsurface MEC/MD. 4. MC Sampling and Analytical Analysis • Discrete MC (explosives) soil samples are proposed beneath all MEC items defined by the criteria presented in **Figure 4-7**. o If the MRS is observed to have multiple MEC items, and sampling is warranted for these items as discussed in **Section 4.2.1**, samples will be collected that are geographically dispersed throughout the MRS. If 20 samples are collected and analyzed for energetics and the results indicate concentrations below the screening levels then MC sampling will no longer be required for the MRS. • Discrete MC (lead) samples will be collected at the Range Complex No. 1 MRS if evidence of small arms debris or a natural berm feature are identified that could have been used as a backstop. • If analytical soil sample results show presence of MC above the screening levels established in the RI Work Plan, then additional surface and subsurface samples will be collected to establish the vertical and horizontal extent of soil impacted by small arms contamination. If a significant soil impact is determined *(i.e., MC are above human health screening levels)* and the nearby sediment, surface water, or groundwater pathways are potentially complete, then sampling and analysis of those media will be performed provided that the criteria for such sampling as identified in **Sections 4.2.1** are met. • In-situ XRF screening for lead in soils – For field information only and to help assist the field teams where to collect samples for laboratory analysis • Analytical data will be collected as necessary for all decision-making purposes • Refer to **Section 4.2.1** for discussion regarding sampling for lead as an indicator for small arms MC. • Discrete MC (explosives) soil samples are proposed beneath all MEC items

Table 3-2 Data Quality Objectives for the Range Complex No. 1 MRS (Continued)

Step	Data Quality Objective
	defined by the criteria presented in **Figure 4-7** and discussed in **Section 4.1.5**. 5. If MC samples are collected, analytical results will be used to perform a Baseline HHRA (**Section 7.1**) and a BERA (**Section 7.2**). 6. MEC HA using the USEPA MEC HA Methodology (Interim) (USEPA, 2008) will be performed whether or not MEC is found (**Section 7.3**) When AVS, DGM, intrusive investigations, and MC sampling are performed in accordance with the SOPs, DQOs specified in the GIP, and the UFP-QAPP, then adequate data to perform a MEC HA and MC risk assessment for the PACR will have been collected. The RI will have provided sufficient data necessary to support decision-making regarding the progression of the PACR through the CERCLA process.
6. Specify performance or acceptance criteria	Data collected will be of the quantity and quality necessary to provide technically sound and defensible assessment of potential risks to human health and the environment and will support the determination of potential explosive hazard. Assisted visual surveys, geophysical surveys, intrusive investigations, and MC sample collections are proposed to occur in accordance with the USACE Three Phase Inspection Process, as presented in Section 4.0 of the RI Work Plan, and will meet or exceed the level of QA/QC established for this project. Analytical data will meet the UFP-QAPP requirements for data quality and usability as presented in Appendix D of the RI Work Plan (HDR, 2013).
7. Develop the plan for obtaining data	The plan for obtaining data was developed through the TPP and presented within the RI Work Plan. Information inputs gathered during the RI will be used to develop a determination of potential hazards associated with MEC, and of potential risks posed by MC directly attributable to munitions contamination within the spatial confines of this RI. An FS will be performed to develop and screen remedial response alternatives.

Notes:
ASR – Archive Search Report
BERA - Baseline Ecological Risk Assessment
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
DGM – Digital Geophysical Mapping
DoD – Department of Defense
DQO – Data Quality Objective
FUDS – Formerly Used Defense Sites
GIS – Geographic Information System
HHRA - Human Health Risk Assessment
INPR – Inventory Project Report
MC – Munitions Constituents
MD – Munitions Debris
MEC – Munitions and Explosives of Concern
MEC HA - MEC Hazard Assessment
MRS – Munitions Response Site
PACR – Port Angeles Combat Range
QA/QC - Quality Assurance/Quality Control Project Plan
RI – Remedial Investigation
ROE – Right of Entry
SI – Site Inspection
TPP – Technical Project Planning
UFP-QAPP – Uniform Federal Policy Quality Assurance
USACE – United States Army Corps of Engineers
USEPA – United States Environmental Protection Agency
UXO – Unexploded Ordnance *XRF – X-ray Fluorescence*

3.5.1 Data Management

Data produced in association with all aspects of the RI are maintained on secure servers. All mapping products such as AVS, soil screening locations, locations of MEC, etc., will be submitted in compliance with *DID MMRP-09-007.01, Geospatial Information and Electronic Submittals* (USACE, 2009). All GIS data is subject to the same storage, restoration, and security protocols as outlined in **Section 3.5.1.1.**

3.5.1.1 MAPPING

Data and figures are presented in NAD1983 Washington State Plane Coordinates North Zone, U.S. Survey Feet. Some of the raw data collected during the investigation is inherently based upon Universal Transverse Mercator (UTM) coordinates. Any data collected utilizing UTM coordinates will be provided as both UTM (raw) data and State Plane (project coordinate system).

3.5.1.2 MUNITIONS AND EXPLOSIVES OF CONCERN TRACKING

The locations of all MEC items found during the RI field investigation were recorded on the Trimble GeoXH GNSS units carried by each field team. The data was then downloaded to the GIS database for tracking and mapping of the results. Photograph locations also were recorded and tracked. The photograph locations are included in the Photograph Documentation Log (**Appendix C**).

4.0 Characterization of MEC and MC

This section summarizes the approaches used to complete the RI and the activities conducted to characterize MEC and MC at the site.

4.1 Munitions and Explosives of Concern Characterization

4.1.1 Survey Control

A State of Washington licensed surveyor was contracted to establish geodetic survey control to be utilized as a spatial reference frame for the DGM and AVS activities. A total of six control points were established. The following specifications were met during the geodetic survey:

Horizontal Specifications:

- Horizontal Datum: NAD83
  - Realization: 2011 Adjustment
  - Epoch: 2010.00
- Projection: Washington State Plane, North Zone
- Absolute Horizontal Accuracy (relative to true datum): +/- 4 centimeters (cm) at the 95% confidence interval (1.96 sigma)
- Relative Horizontal Accuracy: +/- 2 cm at the 95% confidence interval (1.96 sigma)
- A minimum of three National Geodetic Survey (NGS) control stations relative to the horizontal datum were utilized during the establishment of the project control points.
- Linear Units: Meters and U.S. Survey Feet

Vertical Specifications:

- Vertical Datum: North American Vertical Datum of 1988 (NAVD88)
- Geoid Model: NGS Geoid12A
- Absolute Vertical Accuracy (relative to true datum): Not Applicable
- Relative Vertical Accuracy: +/- 2 cm at the 95% confidence interval (1.96 sigma)
- Linear Units: Meters and U.S. Survey Feet

Monumentation Specifications:

- Survey control monuments consisted of No. 4 rebar with cap at least 24 inches long.

All data and deliverables generated by the State of Washington licensed surveyor (**Appendix D**) were reviewed and approved by the Project Geodesist. Independent QC measurements were collected by the field investigation team to verify the relative spatial accuracy.

4.1.2 Assisted Visual Surveys

AVS were performed during the field investigation at the MRS. The AVS included observations of surface and subsurface MEC/MD, evidence of small arms activity, as well as any other features relevant to the CSM such as water features, nearby receptors, etc. The AVS team conducted real-time intrusive investigations on subsurface anomalies in areas where the use of DGM was not practical. DGM was not practical in areas with limited access, heavy vegetation, and steep topography.

4.1.2.1 ASSISTED VISUAL SURVEY PLANNING AND FIELD COORDINATION

During planning activities, the MRS was separated into Technical Approach Areas 1, 2, and 3 due to its size and for purposes of organizing and coordinating the field effort. The Technical Approach Areas were based on the types of munitions used, how the munitions were fired, the types of investigation methods required to delineate nature and extent, and the ability to implement the technology available at the time of the RI. Site-specific limitations such as topography and vegetation were also considered when determining the Technical Approach Areas. **Figure 4-1** presents the technical approach areas.

4.1.2.2 ASSISTED VISUAL SURVEY METHODOLOGY

A UXO Technician III functioned as the Team Leader and used either a Schonstedt magnetometer or White's all-metals detector to locate surface and sub-surface anomalies. Vegetation was cleared by hand or with hand tools, when practical, to navigate the transect. A UXO Technician II operated a Trimble GeoXH GPS unit to navigate, record the path of travel and to record any findings (including photographs). Within the areas that required DGM or environmental sampling the UXO Technician II was replaced by a Field/Geophysical Technician. The Field/Geophysical Technicians were not present during the subsurface investigations. A minimum of one UXO Technician III and one UXO Technician II performed the subsurface investigations during the AVS. To the maximum extent practicable, the AVS team walked transects along terrain contours and perpendicular to the firing line. For areas where physical barriers or manmade features were present (e.g., structures, equipment, land features) the teams diverted around the barrier and reacquired the transect pathway once the barrier was bypassed.

Planned transects were uploaded to the Trimble GeoXH GPS unit and the AVS team navigated along each planned transect using the GPS. The GPS system was configured to record position data at maximum intervals of one minute or no more than 50 feet along each transect to create a permanent record of where each team walked. If MEC or MD were identified along the transect path, the location was stored in the GPS along with a brief description of the findings. The GPS track path and findings along each transect were uploaded to the project GIS database in order to create a permanent record of the actual path followed. The spatial distribution of MEC, MD, small arms or evidence of historical munitions use were analyzed and used to refine the extents of the MRS.

4.1.2.3 ASSISTED VISUAL SURVEY TECHNOLOGIES

Schonstedt Model GA-52 Cx Metal Detector – The Schonstedt GA-52 Cx metal detector has been the industry standard for 35 years. It is a hand-held, analog, fluxgate magnetometer equipped with five sensitivity settings. It emits an audio tone that peaks in frequency when the instrument's tip is directly over a ferrous item. The magnetometer does not detect nonferrous material such as aluminum and brass.

White's MXT 300 All-Metals Detector – The White's MXT 300 all-metals detector is a handheld, high performance all metals detector with multiple operating modes and a liquid crystal display. It has an operating frequency of 15 kilohertz, a drop-in battery pack, and a waterproof 12-inch search coil. Gain, threshold and dual controls allow for adjustable sensitivity and maximum discrimination for items at variable depths.

Trimble Model GeoXH GPS - The Trimble GeoXH GPS unit is a high performance, dual-frequency Global Navigation Satellite System (GNSS) receiver and antenna with Everest™ multipath rejection technology and Floodlight technology, sub-meter GPS receiver combined with a rugged handheld computer. The computer runs Microsoft Windows Mobile Version 6.5 powered by a TI OMAP 3503 processor. The Trimble GeoXH GPS is weatherproof and is powered by a rechargeable battery. The unit contains a built in 5.0 mega-pixel, auto-focus camera. As each photo was taken, it was geo-tagged with the location of the Trimble GeoXH GPS allowing for seamless integration with existing data capture workflows. The camera's lens allows for both wide-angle and close-up photographs and the geo-coded images can be converted into "layer files" for GIS.

4.1.2.4 ASSISTED VISUAL SURVEY QUALITY CONTROL PROCEDURES

Calibration Procedures - At the start of each field day, the visual survey teams validated the Trimble GeoXH units at an established control point to ensure the units were functioning properly and returning correct positional information. If an established control point was unavailable, positions from the Trimble GeoXH were compared to each other to verify proper operation.

At the start of each field day, the Schonstedt metal detector was held 12 inches above ground surface and was passed over an instrument verification strip (IVS) (described in **Section 4.1.3**) containing inert 37mm projectiles (<1-foot bgs) to confirm that the instrument was functioning properly.

To ensure instrument functionality, each instrument operator was required to sweep the IVS using the sweep techniques and instrument settings proposed for the project at least once a day (Section 3.4.1 of the RI Work Plan), and detect 100% of the items. There were no data generated during the verification of analog detectors. The results of the test resulted in a "go" or "no-go" decision. There were no instances of instrument failure during the RI.

Daily Site Report - The Site Manager was responsible for documenting the day's field activities and significant items in a Daily Site Report (DSR). The DSR provided a standardized format to document the AVS team activities, hours and locations of fieldwork, significant items recorded, weather conditions, photographs of items recorded and terrain, or any other pertinent information that required formal documentation. The DSRs are included in **Appendix E**.

Daily Quality Control Report - The UXO Quality Control Specialist (UXOQCS) was responsible for documenting the day's field activities in a Daily Quality Control Report (DQCR). The DQCR provided a standardized format to document the visual survey team activities, hours and locations of fieldwork, verification of data quality procedures, weather conditions, circumstances that affected the quantity or quality of the survey, or any other pertinent information that required formal documentation. The DQCRs are included in **Appendix E**.

4.1.2.5 ASSISTED VISUAL SURVEY ACTIVITIES SUMMARY

Assisted visual surveys were conducted from October 24 to December 11, 2013, at the Range Complex No. 1 MRS. The total transect mileage from the Trimble units for all three Technical Approach Areas was 112 miles as illustrated on **Figure 4-1**. Assisted visual survey transects were planned and executed based on the technical approach areas described below.

Technical Approach Area 1 - Transects were spaced approximately 150 feet apart (**Figure 4-1**).

Technical Approach Area 2 – The majority of the transects were spaced approximately 75 feet apart; however, some of the transects were spaced 35 feet apart. The transects that were spaced 35 feet apart were collected within an area that was historically an open meadow that contained the target features. This area was determined from a historic aerial photograph analysis. The historic photograph analysis utilized the dataset closest to the ranges post operational status (i.e., 1956) (**Figure 4-1**).

Technical Approach Area 3 - Transects were spaced approximately 75 feet apart within the intended impact area per the ASR and the immediately adjacent 300 feet buffer area. Transects were spaced at approximately 150 feet apart outside the intended impact/300 feet buffer area (**Figure 4-1**).

The physical boundary of the Range Complex No. 1 MRS, defined at the conclusion of the SI, was 2,629 acres. The project GIS boundary provided by USACE was determined to be 2,629.8 acres. The spatial boundary determined during this RI is 1,286.3 acres and is constrained to areas within the FUDS eligible property where ROEs were obtained.

During the AVS, 718.5 acres of the Range Complex No. 1 MRS were surveyed. The USACE did not receive ROE for three parcels that overlapped the eastern boundary of the MRS, consequently 105.9 acres were not surveyed (**Section 2.2.4**). The ONP was not surveyed due to the NPS and the DoD not having a programmatic agreement to address MMRP sites. During the AVS, a total of 567.8 acres were classified as unsurveyable due to dense vegetation, steep slopes, wetlands, and streams. **Figure 4-2** shows representative terrain associated with unsurveyable areas. Total original MRS project acreage increased from 2629.8 acres to 2630.7 acres. The additional acreage is discussed further in **Section 8.5.1**.

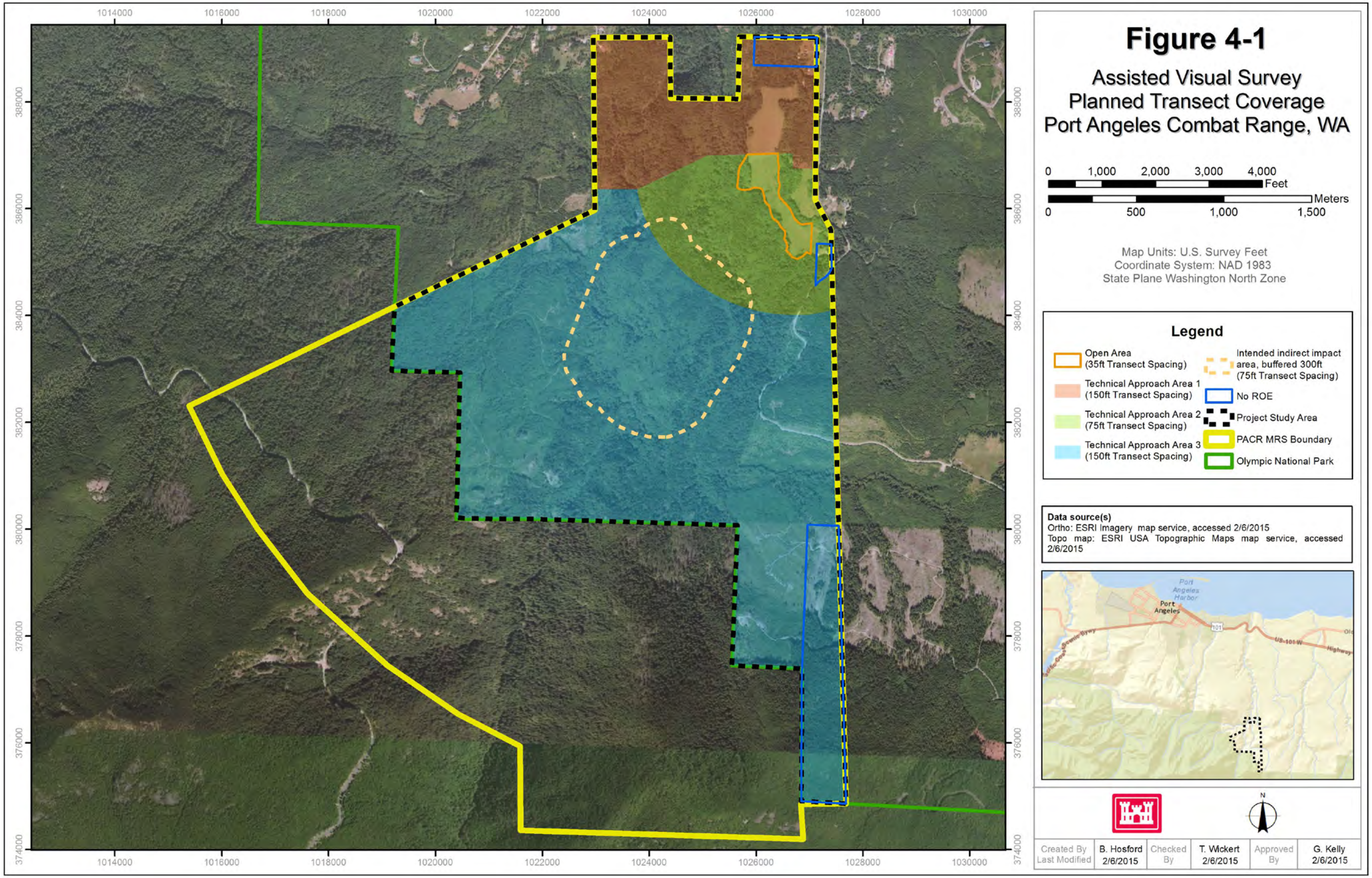
Figure 4-1
Assisted Visual Survey
Planned Transect Coverage
Port Angeles Combat Range, WA
0 1,000 2,000 3,000 4,000
Feet
Meters
0 500 1,000 1,500
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
Open Area (35ft Transect Spacing)
Technical Approach Area 1 (150ft Transect Spacing)
Technical Approach Area 2 (75ft Transect Spacing)
Technical Approach Area 3 (150ft Transect Spacing)
Intended indirect impact area, buffered 300ft (75ft Transect Spacing)
No ROE
Project Study Area
PACR MRS Boundary
Olympic National Park
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Port Angeles Harbor
Port Angeles
101
N
Created By Last Modified
B. Hosford 2/6/2015
Checked By
T. Wickert 2/6/2015
Approved By
G. Kelly 2/6/2015
1014000
1016000
1018000
1020000
1022000
1024000
1026000
1028000
1030000
388000
386000
384000
382000
380000
378000
376000
374000

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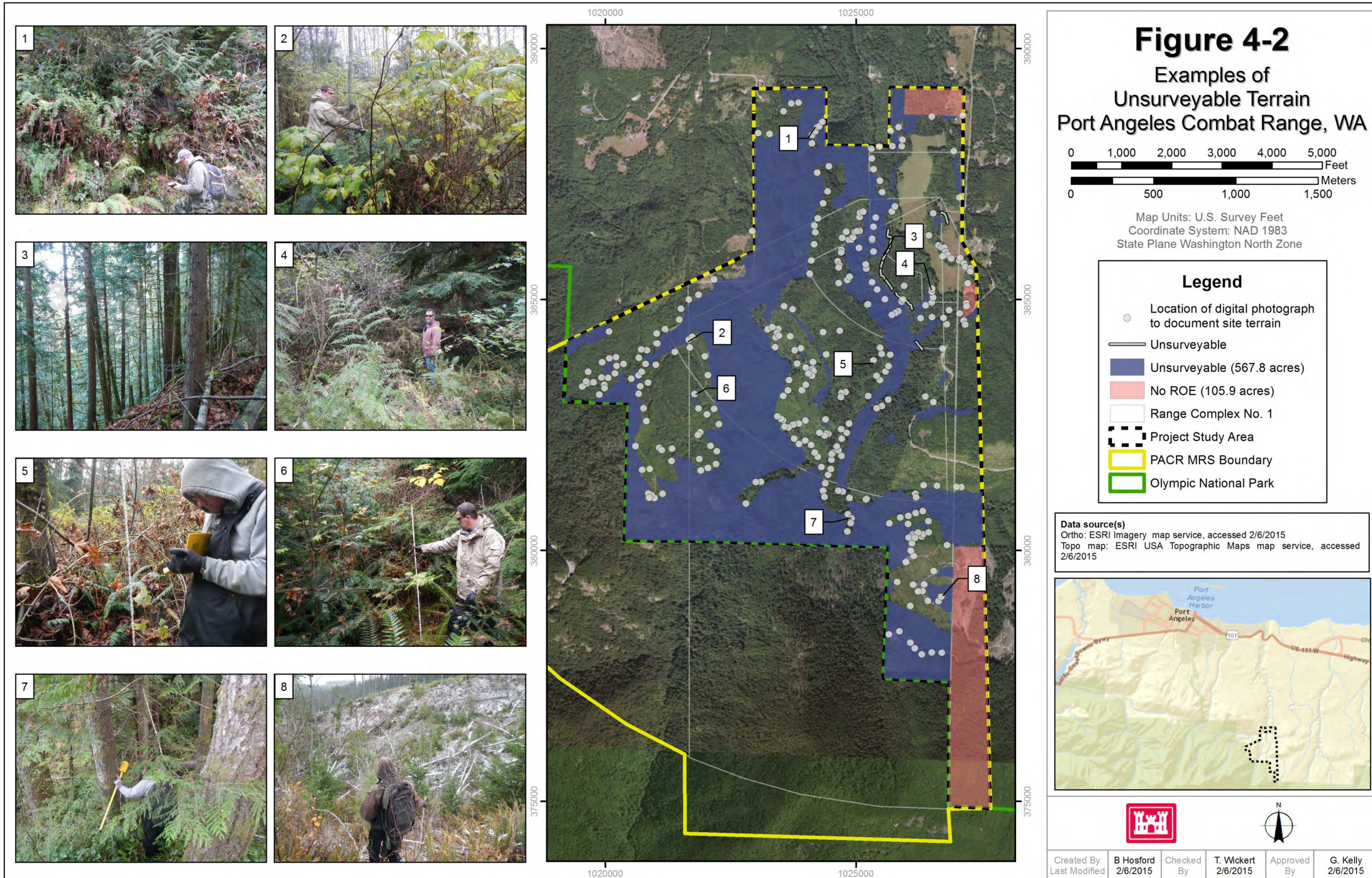
1
2
3
4
5
6
7
8
1020000
1025000
390000
385000
380000
375000
Figure 4-2
Examples of Unsurveyable Terrain Port Angeles Combat Range, WA
0 1,000 2,000 3,000 4,000 5,000 Feet
0 500 1,000 1,500 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
Location of digital photograph to document site terrain
Unsurveyable
Unsurveyable (567.8 acres)
No ROE (105.9 acres)
Range Complex No. 1
Project Study Area
PACR MRS Boundary
Olympic National Park
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Port Angeles
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Created By Last Modified
B Hosford 2/6/2015
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G. Kelly 2/6/2015

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4.1.3 Digital Geophysical Mapping Investigation

The objective of the DGM surveys was to determine whether a MEC subsurface hazard may exist by mapping and selecting metallic anomalies within areas that may contain target features.

The DGM process is described in detail in the Geophysical Investigation Plan (Section 3.4 of the RI Work Plan). DGM was used to identify areas exhibiting high anomaly densities indicative of munitions within Technical Approach Area 2. DGM transects were walked at a spacing of 35 feet or 75 feet using a Geonics EM61-MK2 (EM61-MK2) sensor mounted on a man portable non-metallic litter. Any additional suspected munitions related features outside the pre-determined transect spacing (35 feet or 75 feet) within areas assigned to Technical Approach Area 2 were also captured. The EM61-MK2 could not be operated reliably on slopes greater than 65%. The transect spacing was determined using the Visual Sample Plan (VSP) software and spacing agreed upon with the regulatory agencies. VSP is a software program developed by Pacific Northwest National Laboratory under funding from the Strategic Environmental Research and Development Program (http://vsp.pnl.gov) (**Section 5.1.1.2**). It utilizes statistical sampling theory and statistical analysis of sample results to provide a defensible sampling plan. Typically, 1% - 20% of an area is mapped during such a sampling activity.

4.1.3.1 DIGITAL GEOPHYSICAL MAPPING DATA COLLECTION AND METHODOLOGY

The DGM methodology for this RI was developed in accordance with the *Data Item Description (DID) MMRP-09-004, Geophysics* (USACE, 2009a), *Engineering Manual (EM) 1110-1-4009* (USACE, 2007), *Digital Geophysical Mapping Guidance Operational Procedures and Quality Control Manual (DGM QC Guidance)* (USACE, 2003), and *Geophysical System Verification (GSV): A Physics-Based Alternative to Geophysical Prove-Outs for Munitions Response* (Environmental Security Technology Certification Program) (ESTCP, 2011).

4.1.3.2 DIGITAL GEOPHYSICAL MAPPING TECHNOLOGIES AND PERFORMANCE METRICS

Geonics EM61-MK2 - This survey used an EM61-MK2 metal detector deployed using a man-portable platform. Time-domain electromagnetic metal detectors detect shallow metallic objects with good spatial resolution and with minimal interference from adjacent metallic features. The EM61-MK2 is the industry standard metal detector. The instrument generates a transient primary magnetic field, which induces eddy currents in nearby metallic objects. As the eddy currents decay, the instrument measures the secondary magnetic field over four geometrically spaced time windows. The first measurement occurs a relatively long time after the primary pulse. This allows current induced in the ground to dissipate, leaving only the magnetic field produced by nearby metallic objects. The secondary magnetic field induces a current in the coils, which the instrument electronics convert to a voltage. The Data Acquisition System (DAS) timestamps and records the voltage. The instrument collected data at 12 Hertz (Hz) or samples per second. The EM61-MK2 was designed to detect individual small items at shallow depths and relatively larger items (e.g., 155mm projectile) at depths approaching 5 to 7 feet (1.5 to 2.1 meters). The resulting data was used to differentiate, in simplistic fashion, the relative size and distance (or depth) of metal items when the anomaly density is relatively low. In cluttered areas where the anomaly density is relatively high (e.g., burial pits, trenches, etc.) and the anomaly signatures overlap, the determination of size and depth is much more difficult. The data streams from these sensors were collected using a DAS and stored on a computer hard drive. After data collection, the data are downloaded, processed and analyzed, resulting in an anomaly list.

EM61-MK2 Litter - Due to thick vegetation and rough terrain in the Direct Fire Impact Area, the man-portable litter platform was used to collect DGM data. A single EM61-MK2 coil was attached to a fiberglass frame that allowed two geophysical team members to hold the coil, suspended above the ground, while maintaining a distance away from the coil large enough to prevent personnel interference. The coils height above the ground surface was 9-12 inches (30 cm). The orientation of the sensor was controlled by the geophysical technicians manually lifting or lowering the handles of the litter platform. The geophysical technician operating the rear end of the litter used frequent visual checks to maintain a level orientation. A real-time kinematic (RTK) GPS antenna was positioned directly above the center of the coil. Both the GPS antenna and the EM61-MK2 coil were powered by portable batteries located inside of the GPS antenna and backpack worn by the geophysical team member supporting the rear end of the litter. This backpack also contained the EM61-MK2 control box. The geophysical team member supporting the front end of the litter platform wore a harness with a laptop computer attached and was responsible for navigating to the survey lines and controlling the DAS. The geophysical team members also wore a waist strap with loops that attached to the litter platform handles to help maintain a fixed coil height and to allow occasional hands free operation when the front end team member was operating the computer. The litter was not able to survey in areas too difficult to walk through or areas with widespread vegetation that would prevent the coil from maintaining a specified height. **Table 4-1** outlines the DGM DQOs for the litter platform standardization tests.

Trimble Real Time Kinematic Positioning - To position the EM61-MK2 geophysical sensor a GNSS receiver and antenna were utilized. A GNSS receiver is similar to a GPS receiver except that it utilizes multiple satellite constellations, specifically the U.S. GPS satellite constellation and the Russian Global Navigation Satellite System (GLONASS) satellite constellation. GNSS technology used the broadcasts from a minimum of five Earth orbiting satellites to triangulate the antenna's geographical location. A local GNSS base station provided differential corrections via a radio link to correct for systematic errors, such as atmospheric distortions. The rover was typically within 0.5 miles of the base station. Due to dense vegetation and tree canopy at Technical Approach Area 2, a characterization accuracy of +/- 3 feet (1 meter) was utilized.

Man-portable EM61-MK2 litter platform with RTK Positioning

4.1.3.3 DIGITAL GEOPHYSICAL MAPPING QUALITY CONTROL PROCEDURES

Digital Geophysical DQOs are presented in **Table 4-1**. The standardization tests mentioned in the sub-sections below (static background and spike, personnel, cable shake, time calibration, and point position) and the IVS are checked against the DQOs for project QC compliance.

Table 4-1 Digital Geophysical Data Quality Objectives

Data Quality Objective	Test Method	Measurement Performance Criteria
Equipment warm-up (minimum 15 minutes)	A power on, conduct real time monitoring of EM61-MK2 instrument readings. Data is not recorded; this will be a visual check by the field team prior to starting calibration tests.	Drift of less than 3 mV over 3 minutes
Repeatable static data are being obtained from the DGM system	At the beginning and end of day, conduct a static background and spike test for each coil. Data will be collected for at least 60 seconds for each test.	Less than 2.5 mV peak to peak for static background, spike ±10% of standard item response after background corrections
Prevent noise related to loose pins or cable connectors	At the beginning of the day, conduct a cable shake test. Each cable will be tested for at least 5 seconds while monitored by the sensor operator.	Less than 2.5 mV peak to peak
Ensure instrument operators are not carrying any metallic objects that can interfere with the EM61-MK2 readings	At the beginning of the day, conduct a personnel test (applicable to single coil cart systems only).	Less than 2.5 mV peak to peak
Position of GPS is accurate	At the beginning of the day, the GPS unit's position will be compared with a known point during a point position test. Positions will be recorded for at least 60 seconds.	Within 10 cm of known values for point position test. Only positions with a PDOP below 4 and RTK fix value* of 2, 3, or 4 will be accepted for DGM. Brief spikes of PDOP below 6 may be accepted in limited cases.
Repeatable dynamic data are being obtained from the DGM system	At the beginning and end of the day, the geophysical instruments will collect data over an IVS.	± 25% of prior response; position of anomalies repeatable within 10 cm.
Positioning of detected anomalies is accurate	Anomalies selected will be compared with known seed item locations to ensure compliance.	100% of all anomaly locations lie within a 3-6 feet (1-2 meters) radius of a point on the ground surface directly above the source of the anomaly. For seeds outside of the 3-6 feet (1-2 meters) radius, a corrective action will be conducted to determine the appropriate amount of failed data.
Survey coverage is sufficient to meet project objectives	Results of DGM surveys will be evaluated to ensure compliance.	Transect line gaps will not exceed 10 feet (3 meters) for distances > 13 feet (4 meters). Lot size is the survey file.
Consistent detection of blind seed items during dynamic survey	Transects with fixed RTK GPS coverage will be seeded with ISOs or seed items and surveyed by geophysical personnel.	95% of the ISOs or seed items will be detected. Any misses will result in a root cause analysis and may result in a resurvey of all or a portion of the transect.

Note: *RTK fix value deviates from the DQO presented in the RI Work Plan. The RI Work Plan originally stated RTK fix solutions other than 3 would be removed. Per Field Change Request (FCR) #1, the project team accepted RTK fix solutions of 2, 3, and 4. The project team did not include RTK fix solutions of 1. FCR #1 was approved by USACE during the DGM field investigation (**Appendix E**).

cm – centimeter
DGM – Digital Geophysical Mapping
GPS – Global Positioning System
ISO – Industry Standard Object
mV – millivolt
PDOP – Position Dilution of Precision
RTK – Real-Time Kinetic

Drift was observed occasionally on channel one during static background test. Values were marginally outside range for the performance criteria 2. Results from other tests including cable shake, personnel, and IVS anomaly response values confirmed function. The Project Geophysicist therefore concluded that the marginal channel one drift would not affect target picking and that results of all standardization and GSV tests confirm that DQOs were met. The results of the geophysical standardization tests subject to DQOs may be found in **Appendix F**.

4.1.3.3.1 Digital Geophysical Mapping Quality Control - Instrument Verification Strip

An IVS (shown in **Figure 4-3**) was installed onsite in Grid S-07. This site was selected because it was an area void of subsurface metal and electromagnetic interference. The test strip construction followed the guidelines described in *Geophysical System Verification (GSV): A Physics-Based Alternative to Geophysical Prove-Outs for Munitions Response* (ESTCP, 2009).

Four targets were placed for assessment and RTK-GNSS positioning was obtained on each target. Inert 37mm projectiles were used to simulate munitions targets. The inert 37mm projectile was selected because it was the smallest munition of concern (SMC) based on the range of munitions and munitions related items expected to be found during the survey. **Table 4-2** lists the orientations and locations of the inert 37mm projectiles.

At a minimum, the IVS data was collected twice daily and after any equipment changes. The DQO table (**Table 4-1**) contains the limits for the test, and the Daily Survey and Processing Summary documents the results of the test (**Appendix F**). The inert 37mm projectiles were used to confirm the sensitivity of the geophysical instrumentation and adequacy of the data acquisition parameters (sampling frequency, and positioning system accuracy and precision, and sensor height above the ground surface). This was accomplished by comparing the sensor responses from the inert 37mm projectiles to standardized, physics-based models of the 37mm projectile created specifically for munitions response projects by the Naval Research Laboratory (NRL). Since geophysical measurements of the inert 37mm projectiles in the field varied from the physics-based models, each IVS lane was surveyed multiple times with at least two separate EM61 MK2 systems to establish an average electromagnetic response for each item. This average response was used to determine whether the sensors were functioning properly throughout the duration of DGM activities. Refer to the IVS Memo located in **Appendix G** for further details on IVS objectives, layout, data collection, and data analysis.

The project geophysicist certifies that all DQOs were met during Instrument Verification Strip QC. The results of the geophysical standardization tests subject to DQOs may be found in Attachment A of **Appendix G**.

Table 4-2 Instrument Verification Strip at the Range Complex No. 1 MRS

Item	Burial Depth (feet)	Orientation	Number of Items	UTM Northing (meters)	UTM Easting (meters)	State Plane Northing*	State Plane Easting*
Inert 37mm projectile	0.5	H	1	5319761.216	474599.192	385937.54	1027032.58
Inert 37mm projectile	0.5	V	1	5319763.496	474597.219	385945.20	1027026.32
Inert 37mm projectile	1.0	H	1	5319765.698	474595.386	385952.59	1027020.51
Inert 37mm projectile	1.0	V	1	5319767.953	474593.384	385960.18	1027014.15

Notes:
** U.S. Survey Feet H = Horizontal, Across-Track V = Vertical UTM = Universal Transverse Mercator*

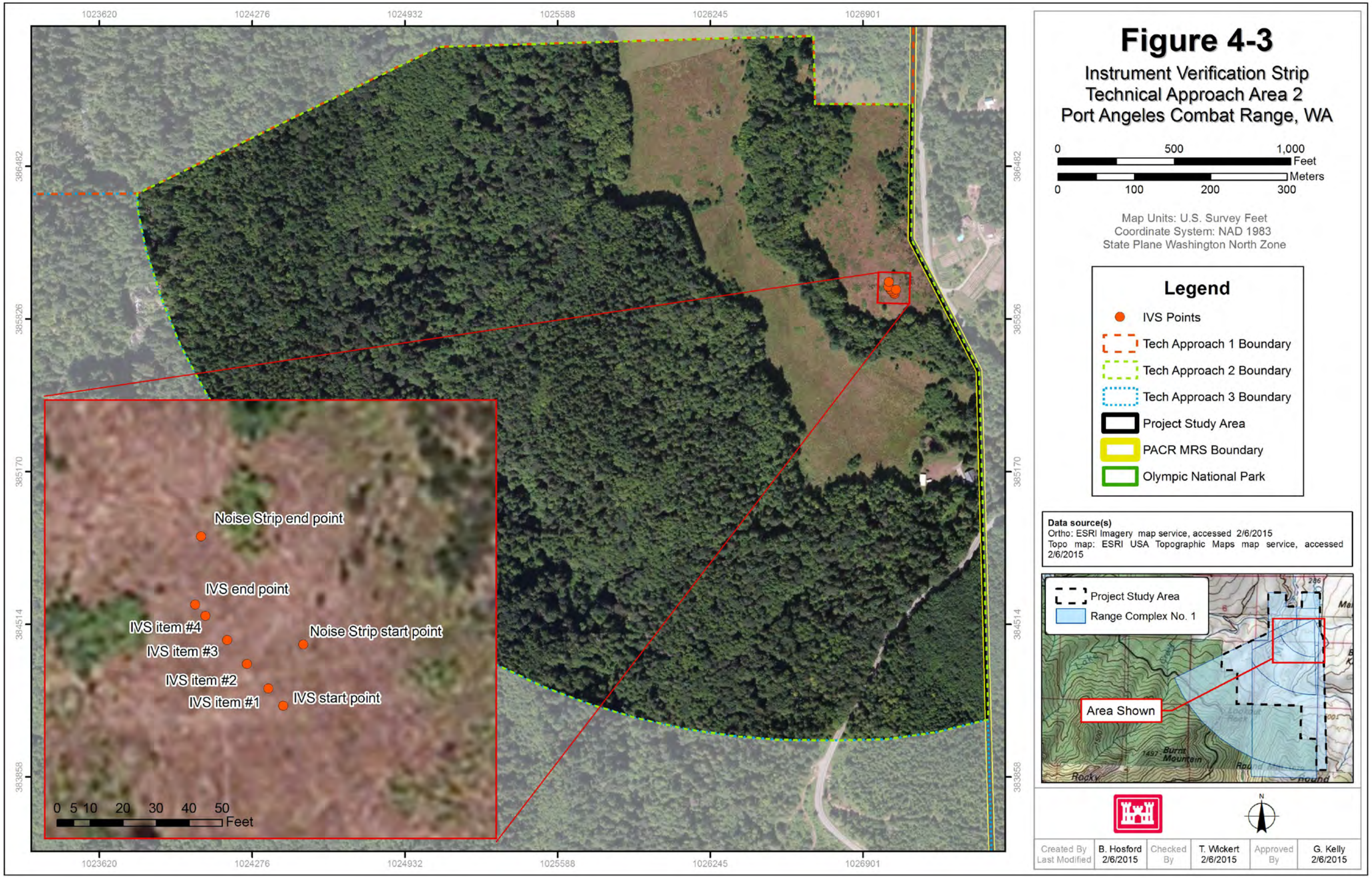
Figure 4-3
Instrument Verification Strip
Technical Approach Area 2
Port Angeles Combat Range, WA
0 500 1,000 Feet
0 100 200 300 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
IVS Points
Tech Approach 1 Boundary
Tech Approach 2 Boundary
Tech Approach 3 Boundary
Project Study Area
PACR MRS Boundary
Olympic National Park
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Project Study Area
Range Complex No. 1
Area Shown
Noise Strip end point
IVS end point
IVS item #4
Noise Strip start point
IVS item #3
IVS item #2
IVS item #1
IVS start point
0 5 10 20 30 40 50 Feet
1023620
1024276
1024932
1025588
1026245
1026901
386482
385826
385170
384514
383858
Created By Last Modified
B. Hosford 2/6/2015
Checked By
T. Wickert 2/6/2015
Approved By
G. Kelly 2/6/2015

4.1.3.3.2 Digital Geophysical Mapping Quality Control - Standardization Tests

In addition to the daily IVS surveys, the following standardization tests were conducted and the results are documented in the Daily Survey and Processing Summary (**Appendix F**).

- The **Static Background** and **Spike Test** checks the instrument's background reading and drift, identifies potential interference, checks the instrument's response against a known standard test item (spike), and checks to make sure the instrument's readings returned to background levels after a spike.
- The **Personnel Test** checks the operators for potential sources of noise, only when a man-portable platform is used for data collection.
- The **Cable Shake Test** measures any anomalous readings caused by cable movement, short circuits, or bad connectors.
- The **Time Calibration Test** measures the time delay (latency) in the instrument readings.
- The **Point Position Test** checks the function and accuracy of the positioning system. Results from the point position test are described below.
- Six survey control points were established by a State of Washington licensed Professional Land Surveyor as a QC measure to ensure that the positional accuracy of the EM61 data met the project DQOs. **Figure 4-4** and **Table 4-3** compares the surveyed locations of the control point with the mapped location of the corresponding geophysical anomaly. Control points 1 and 2 were installed for the base station, therefore they were not placed along EM61 transects. Control point 3 was placed in the open meadow. As expected, the offset between the control point and the corresponding geophysical anomaly was smallest for control point 3 due to the sparse vegetation and open sky visibility. Control points 4 and 6 were in more vegetated areas, and the geophysical anomaly to surveyed position offsets was less than three feet. Control point 5, also located in a vegetated area, had an offset slightly more than three feet. The comparison of the control points established by the licensed Professional Land Surveyor to the geophysical anomalies verified that the DQO for spatial positioning was met.

Table 4-3 Comparative Analysis of Survey Control Point Locations and Associated EM61 Anomaly Response

Description	Control Point Northing* (U.S. Survey feet)	Control Point Easting* (U.S. Survey feet)	Anomaly Northing* (U.S. Survey feet)	Anomaly Easting* (U.S. Survey feet)	Distance Between Control Point and Geophysical Anomaly (U.S. Survey feet)	Sum Channel (mV)
CP-1	385995.85	1027076.41	NA	NA	NA	NA
CP-2	385896.94	1027063.47	NA	NA	NA	NA
CP-3	385822.32	1026558.78	385822.63	1026558.52	0.41	2330.33
CP-4	385726.89	1026407.89	385726.35	1026409.77	1.95	1233.46
CP-5	386479.25	1026434.44	386476.48	1026432.64	3.30	3892.64
CP-6	386194.45	1026097.37	386193.81	1026097.77	0.75	1631.34

Notes: *NA indicates that the control point was placed between planned DGM transects*
**Washington State Plane coordinates (North Zone) U.S. Survey Feet NAD 83*

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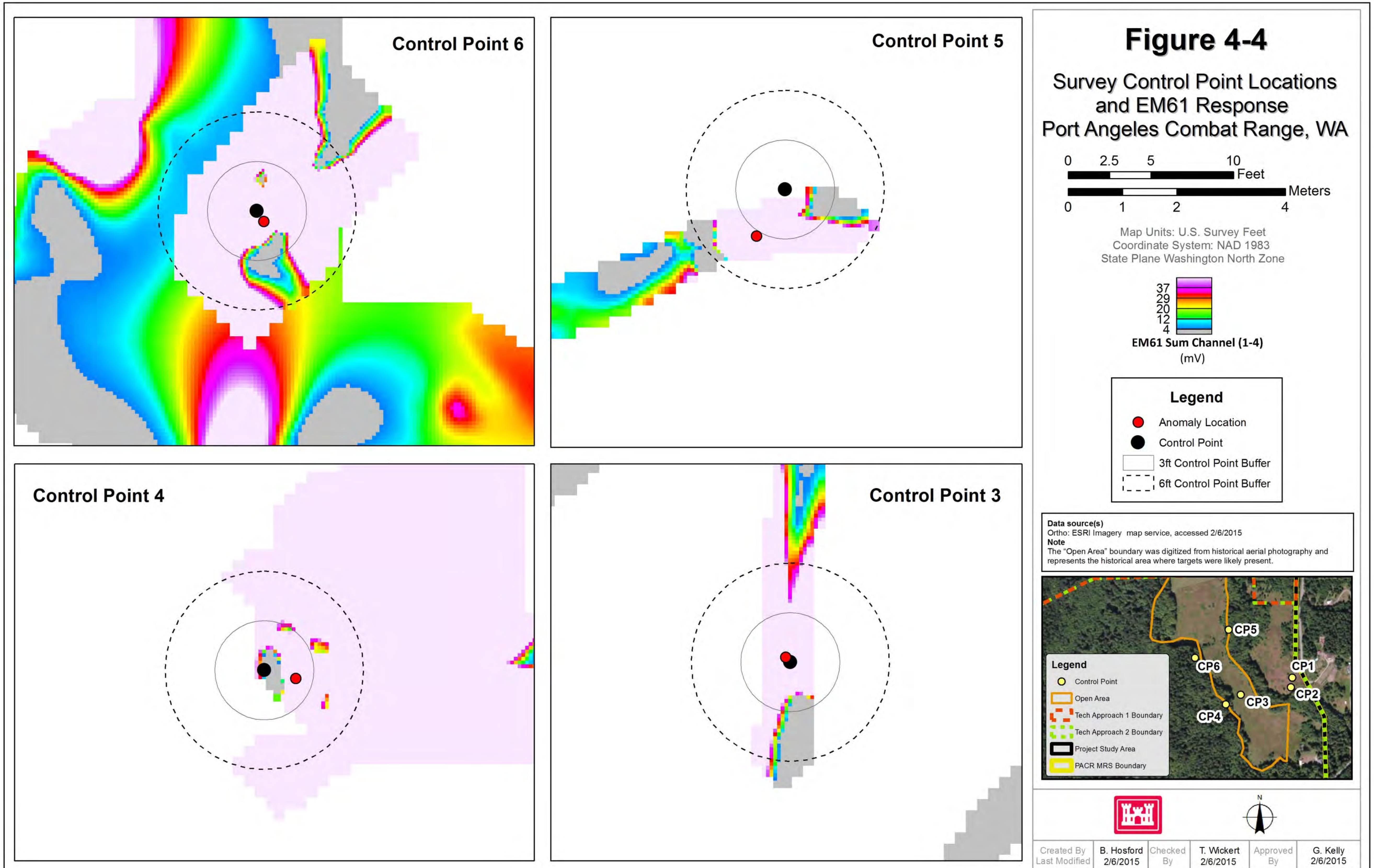
Control Point 6
Control Point 5
Control Point 4
Control Point 3
Figure 4-4
Survey Control Point Locations and EM61 Response Port Angeles Combat Range, WA
0 2.5 5 10 Feet
0 1 2 4 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
37
29
20
12
4
EM61 Sum Channel (1-4) (mV)
Legend
Anomaly Location
Control Point
3ft Control Point Buffer
6ft Control Point Buffer
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Note
The "Open Area" boundary was digitized from historical aerial photography and represents the historical area where targets were likely present.
CP5
CP6
CP1
CP2
CP3
CP4
Legend
Control Point
Open Area
Tech Approach 1 Boundary
Tech Approach 2 Boundary
Project Study Area
PACR MRS Boundary
N
Created By Last Modified
B. Hosford 2/6/2015
Checked By
T. Wickert 2/6/2015
Approved By
G. Kelly 2/6/2015

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4.1.3.4 DIGITAL GEOPHYSICAL MAPPING DATA COLLECTION AND METHODOLOGY

Raw data files collected by geophysical field personnel were posted to a File Transfer Protocol (FTP) site each day after collection and made available to the USACE for QA inspection.

The data processor performed the following initial data checks and processing using UXOLab:

1. The standardization tests (static background and spike, cable shake, personnel, time calibration, point navigation, and IVS) were checked against the DQOs. The standardization results were reported to the Project Geophysicist. Tests with rejected results were repeated. The accepted test results were plotted and analyzed in the daily data processing report.
2. The raw data files were batch processed with a MATLAB script.
   - The EM61-MK2 sensor and GPS positional data were correlated and merged. The time calibration test generates a time slew value that is used to compensate for instrument lag between the geophysical and GPS instruments. The time slew value was entered manually into the MATLAB batch processing script.
   - The script applied a de-median filter to the EM61-MK2 data to reduce the effects of instrument drift.
   - The script also eliminated data points that were collected while the litter array was stationary. Dynamic positional data was required to calculate the correct azimuth of the sensor. The procedure was not performed on the static/spike, cable shake, or point navigation data files because the litter array is intended to be stationary and the azimuth of the sensor is not significant for these tests.
3. The merged data files were exported to a file in xyz format that can be read by Oasis montaj.

Further data processing steps including target picking were performed within Geosoft's Oasis montaj software platform.

1. A Geosoft database file was created by importing all xyz survey files collected on a single day. This database was gridded for visual inspection by the Data Processor. A line path showing where data were collected was produced to aid in the production of status maps.
2. The original database was copied and renamed. GPS data is expressed as a text string using National Marine Electronics Association (NMEA) formatting. In addition to time and spatial information, the NMEA text string lists the type of GPS correction or fix applied to each GPS position as one of the following values:

   1 = Standard Positioning Service GPS fix
   2 = Differential GPS fix
   3 = Precise Positioning Service GPS fix
   4 = RTK GPS fixed solution

   Data with poor quality GPS positions were eliminated by masking the x coordinate values. The project team accepted RTK fix solutions of 2, 3, and 4. GPS data points were defined as poor in quality if the RTK fix value was equal to 1 or the PDOP value was greater than or equal to 4.
3. Data with PDOP values between 4 and 6 were analyzed. The Data Processor determined that these data points were not just brief spikes; therefore, they were assigned a dummy value. The Sum Channel was also created and populated in this database.

4. The database corrected for poor GPS data was copied and renamed. Data that did not exhibit proper decay were eliminated from target picking by masking the x coordinate values. A decay mask channel was also created in the database such that a dummy value indicates poor decay and a value equal to 3 indicates proper decay.
5. The GPS and decay fixed database was copied and renamed. The resulting database was suitable for target picking using the “Pick Peaks Along Profiles” tool in Oasis montaj. This database was reduced to a target pick list by merging all of the database lines and exporting only the database rows that contained a target pick. The target pick list was sent to the Project Geophysicist, and QC target picks were added to the list.

Data grids and line paths were generated for each stage of processing. Comparing the line paths at each stage helped determine the general quality of the DGM data in terms of how vegetation and terrain affected the RTK fix and proper decay of the EM61-MK2.

For the Technical Approach Area 2 (SR-01), the expected ordnance types and their burial depths were initially unknown. Therefore, the data were analyzed to the noise level. The noise level was determined by computing the mean and standard deviation for the select subsections of data transects, and applying the following formula: Noise threshold = mean + 3 × standard deviation. The final noise threshold used was a weighted average of the noise threshold calculated for each of four subsections acquired on the first day of DGM.

Upon finalization, the target pick list was used to generate a full coverage target density map in the open meadow that historically contained artillery targets. To apply transect data to a full coverage estimate, the target density analysis took into consideration that a transect based, not a full coverage, geophysical survey was performed and that the transect density throughout the meadow was variable. Both the raw and processed geophysical data will be included with the final USACE data deliverable package.

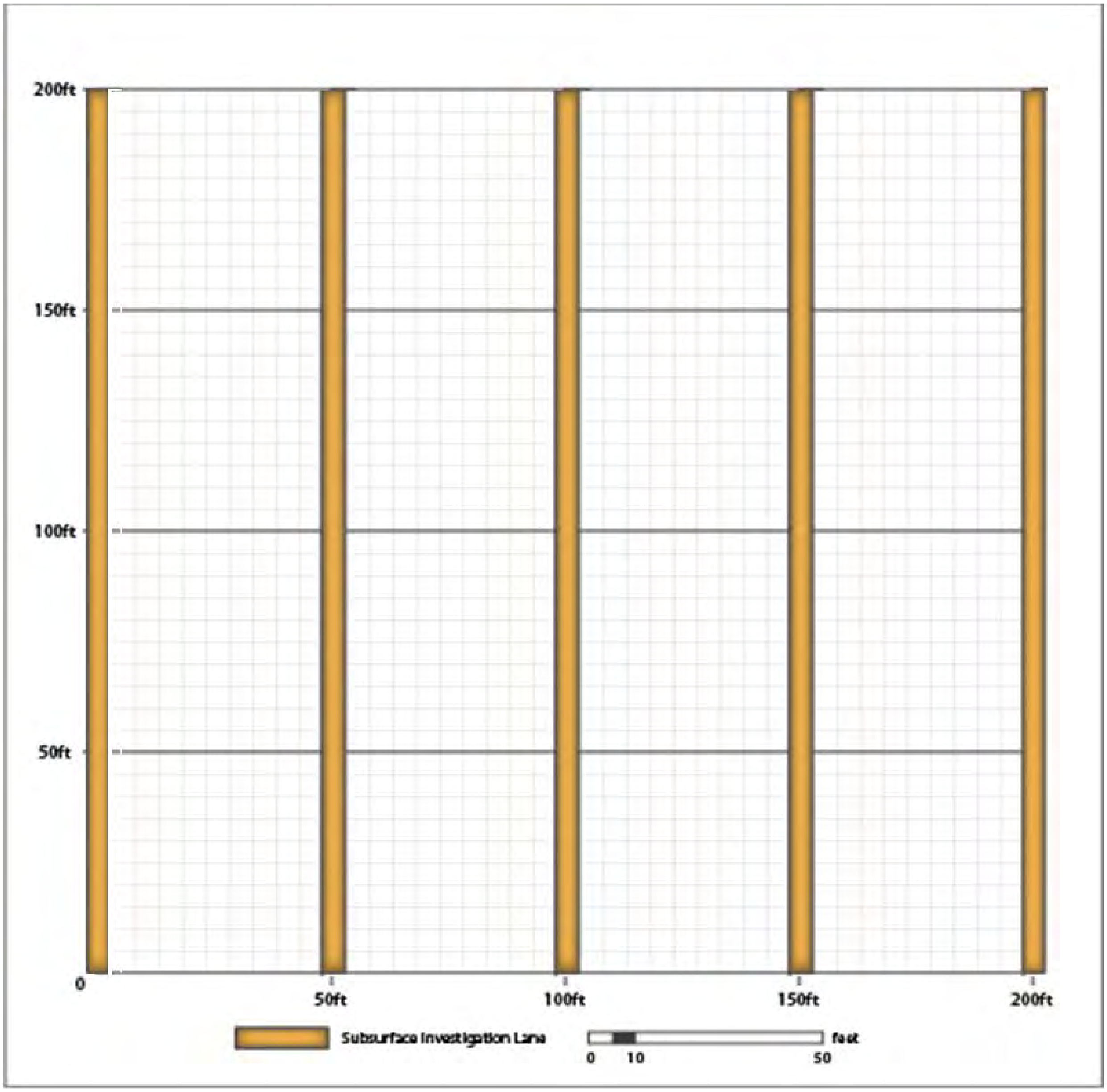
4.1.4 Subsurface Investigation

Once the DGM was completed, and the areas with high anomaly densities (i.e., 250 anomalies per acre or greater) were identified, subsurface investigations were conducted to define the nature and extent of MEC/MD (if present).

4.1.4.1 SUBSURFACE INVESTIGATION METHODOOLOGY

200-foot x 200-foot grids were laid out on each high anomaly density area. Subsurface investigations were performed on a minimum of 10% of the area of each grid. **Figure 4-5** illustrates an example 200-foot x 200-foot grid with 5-foot sweep lanes at the 0-foot, 50-foot, 100-foot, 150-foot, and 200-foot intervals. At every 50 feet on the grid, a 5-foot lane had subsurface anomalies investigated. Contiguous subsurface investigation grids stepping out from high anomaly density areas were established when munitions were observed and until the extent of the munitions were determined. The intrusive investigation did not serve as a removal action but rather to define the nature and extent of MEC/MD.

Figure 4-5 Example of 200-foot x 200-foot Subsurface Investigation Grid



4.1.4.2 SUBSURFACE INVESTIGATION TECHNOLOGIES AND PERFORMANCE METRICS

The same equipment used for the AVS, Schonstedt Model GA-52 Cx Metal Detectors and Trimble Model GeoXH GPS, were used for the subsurface investigations. The same field checks and daily QC checks conducted for the AVS were conducted for the subsurface investigations. Refer to **Section 4.1.2.4** for details. A White's all-metals detector was utilized in the meadow where artillery targets were historically present to look for non-ferrous small arms.

4.1.4.3 SUBSURFACE INVESTIGATION DATA COLLECTION PROCESS/METHODOLOGY

Subsurface investigations commenced on November 14, 2013 and ended on December 11, 2013. A total of 124 grids were investigated. The goal of the operation was to survey at least 10% of the area of each grid. Findings from each grid were recorded using a Trimble GPS. A consolidated summary of MEC, MD, small arms debris, and trash was recorded for each grid.

Subsurface investigations were performed over a period of 15 workdays. As many as 11 UXO Technicians performed the operation. Team members included up to seven UXO Technician IIs and up to four UXO Technician IIIs. A UXO Technician III was team leader. The USACE Ordnance and Explosive Safety Specialist (OESS), a UXO Safety Officer (UXOSO)/UXOQCS, and a Senior UXO Supervisor (SUXOS) were also present at different times to provide oversight, guidance and supervision.

The subsurface investigation consisted of placing a survey stake at the corners (NW, NE, SE, and SW) of each 200-foot by 200-foot (approximately 1 acre) grid using a Trimble GeoXH GPS unit. A section of nylon rope was strung between the corner stakes along the north and south perimeters. In order to survey at least 10% of each grid, the nylon perimeter ropes had metal clips placed on them at 0, 50, 100,150, and 200-foot intervals. Using the clips on the perimeter ropes, 200-foot sections of rope were attached at the clips to create the 5-foot survey lanes in a north to south orientation. A team would walk each 5-foot lane and using a Schonstedt magnetometer or White's all-metals detector (if needed) would identify sub-surface anomalies. The team would then manually excavate the identified anomaly(s) until no additional ferrous items were detected. The team recorded the following information on an Excavation Log for each excavation:

- Whether the item(s) were MEC, MD, Small Arms, or Trash
- Depth of the MEC and MD item(s)
- Consolidated weight of the item(s) per grid in pounds (lbs)
- The number of items
- Comments to further describe the item(s)

A UXO Technician II recorded and photographed the consolidated grid items using the Trimble GeoXH and a digital camera. The UXOSO/UXOQCS and USACE OESS conducted QA/QC review of the activities based on their observations and oversight of selected areas.

4.1.5 MD Handling, MDAS Disposal, and Demolition Operations

During subsurface investigations all Material Potentially Presenting an Explosive Hazard (MPPEH) was inspected in accordance with EM 385-1-97 (USACE, 2008) and EM 1110-1-4009 (USACE, 2007). The MPPEH inspection process is shown in **Figure 4-6** and consisted of the following:

- A UXO Technician II performed a 100% inspection as the item was recovered.
- A UXO Technician III performed a 100% re-inspection.
- The UXOSO/UXOQCS conducted daily audits of the inspection process.
- The UXOSO/UXOQCS insured MPPEH processing was performed safely.
- The SUXOS and UXOSO/UXOQCS performed a 100% inspection at the end of each day to ensure that MD was free of explosive hazards. The resulting MDAS was then secured in a locked container.

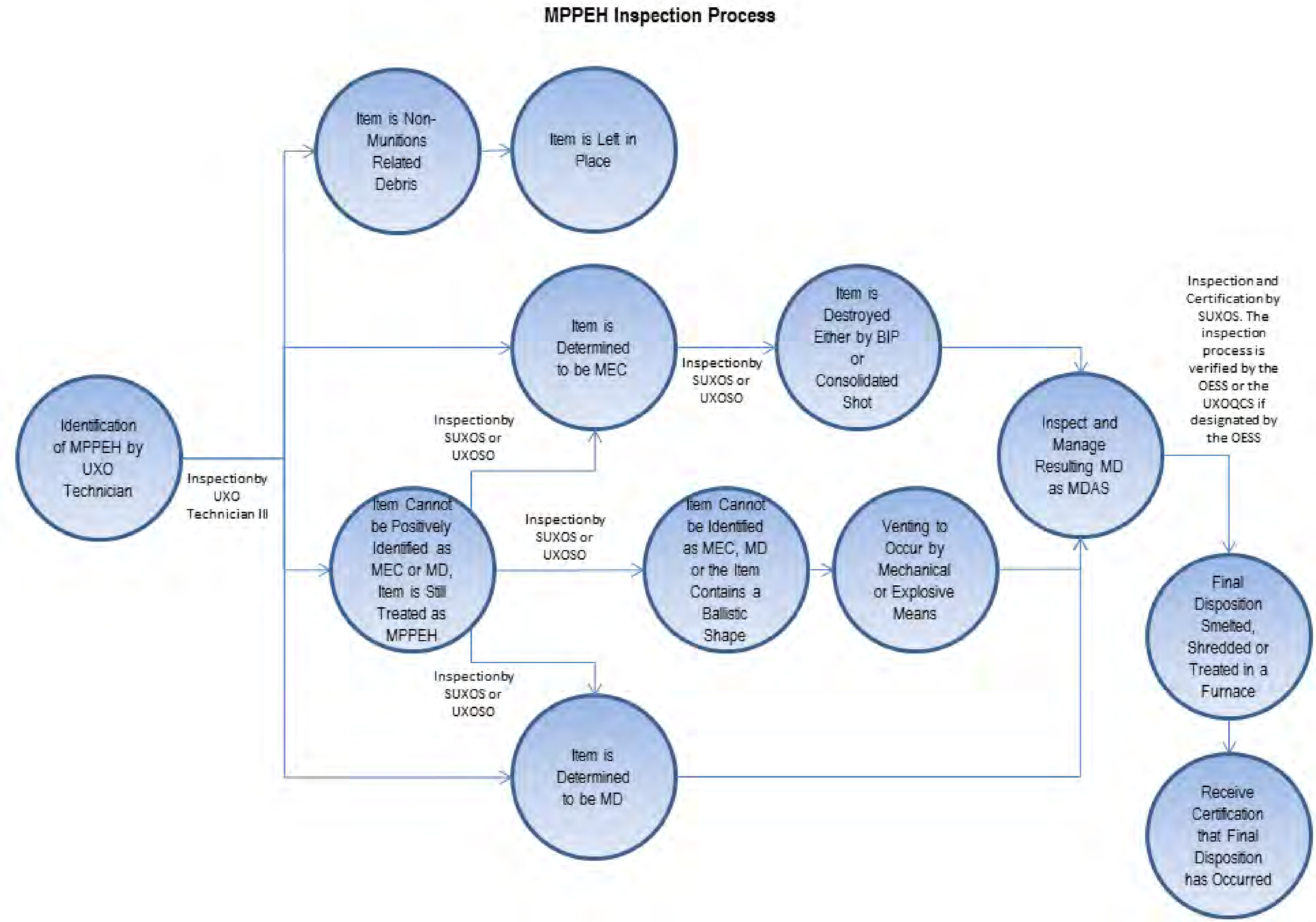
During subsurface investigations, MPPEH was inspected by the SUXOS or UXOSO/UXOQCS to determine if the item was MEC. If the item was determined to be MD, and not MEC, the debris was handled as MDAS. If the items were determined to be non-munitions related debris the items were left in place.

Upon verification of MEC by the SUXOS or the UXOSO/UXOQCS during subsurface investigations, the SUXOS contacted the Project Manager and the Clallam County Sheriff and Fire District #2. The Project Manager then contacted the USACE and relevant stakeholders. Refer to **Section 5.1.1.4** for details regarding demolition of MEC and demilitarization of MD.

The SUXOS and UXOSO/UXOQCS performed a final 100% inspection of the container at the end of the project, completed and sign DD form 1348-1, locked and sealed the container, and arranged for shipping for final treatment. The DD Form 1348-1 was completed to record the items and to certify them as Material Deemed As Safe (MDAS) and establish a chain of custody (**Appendix I**)

All demolition operations were conducted in accordance with the RI Work Plan (HDR, 2013) and the Explosive Site Plan (HDR, 2013a). See **Section 5.1.1.4** for additional information.

Figure 4-6 Material Potentially Presenting an Explosive Hazard - Inspection Process



4.2 Munitions Constituents Characterization

4.2.1 Media Sampling Activities

Media sampling and analysis was included in the RI Work Plan (HDR, 2013) to determine levels of MC contamination if warranted. During the SI, media sampling was performed including surface soil (0-6 inches bgs). The results of the SI indicated that none of the results exceeded regulatory screening values and further MC sampling and analysis was recommended for NDAI. Because the SI did not consider subsurface soil (greater than 6 inches bgs) MC sampling was still considered during the RI. The types of media to be sampled, and locations and numbers of samples and analytes to be evaluated were based on the potential MC sources (refer to **Table 4-4**), as supported by historical records of MEC use, evidence of MEC or small arms debris/activity observed at the MRS during the AVS, and the intrusive investigation. Soil sampling was anticipated to be the primary media investigated, but sediment, surface water, and groundwater sampling were also recommended if it was determined that MC was potentially impacting these media. Media sampling and analysis were to be performed as described in detail in the *Uniform Federal Policy-Quality Assurance Protection Plan UFP-QAPP* (Appendix D of the RI Work Plan).

Table 4-4 Composition of Munitions Potentially Used at the MRS

Size/Type Sub-Range	Nomenclature	Munitions Constituent(s)	Reference
.30 Caliber R01-SR-01	M2/ Ball M/2 AP	Lead; Propellant – single-base (nitrocellulose) or double-base (nitrocellulose and nitroglycerin); Tracer composition – strontium nitrate, polyvinyl chloride, strontium peroxide, magnesium powder.	TM 43-0001-27
.30 Caliber	M1 Carbine	Lead; Propellant – single-base (nitrocellulose) or double-base (nitrocellulose and nitroglycerin); Tracer composition – strontium nitrate, polyvinyl chloride, strontium peroxide, magnesium powder.	TM 43-0001-27
.45 Caliber R01-SR-01	M1911/ Ball with M1 Tracer	Lead; Propellant – single-base (nitrocellulose) or double-base (nitrocellulose and nitroglycerin); Tracer composition – strontium nitrate, polyvinyl chloride, strontium peroxide, magnesium powder.	TM 43-0001-27
.50 Caliber R01-SR-01	M2/Ball M/2 AP with Tracer	Lead; Propellant – single-base (nitrocellulose) or double-base (nitrocellulose and nitroglycerin); Tracer composition – strontium nitrate, polyvinyl chloride, strontium peroxide, magnesium powder.	TM 43-0001-27

Table 4-4 Composition of Munitions Potentially Used at the MRS (Continued)

Size/Type Sub-Range	Nomenclature	Munitions Constituent(s)	Reference
Projectile, 37mm All remaining sub-ranges	M/63 HE with fuze M58 w/ Primer w/ Propellant	M63 HE: Steel (chromium, copper, iron, nickel); Explosive – TNT: Fuze M58 – lead azide, tetryl; Primer M23 – Black powder (sulfur, potassium nitrate, charcoal), primer mixture (mercury fulminate, potassium chlorate, antimony sulfide); Propellant – FNH powder (nitrocellulose, dibutylphthalate, dinitrotoluene, diphenylamine).	TM 43-0001-28
	M74/AP w/Tracer w/ Primer w/ Propellant	M74 AP: Steel (chromium, copper, iron, nickel); Tracer – Tracer composition (strontium nitrate, polyvinyl chloride, strontium peroxide, magnesium powder); Primer M23 – primer mixture (mercury fulminate, potassium chlorate, antimony sulfide); Propellant – FNH powder (nitrocellulose, dibutylphthalate, dinitrotoluene, diphenylamine).	
	M51/TP w/Primer M23 w/Propellant	M51 TP: Steel (chromium, copper, iron, nickel); Primer M23 – primer mixture (mercury fulminate, potassium chlorate, antimony sulfide); Propellant – FNH powder (nitrocellulose, dibutylphthalate, dinitrotoluene, diphenylamine).	
Mortar, 60mm All remaining sub-ranges	M49/HE w/ primer w/ Propellant w/ Ignition ctg w/ fuze M52	M49 HE: Steel (chromium, copper, iron, nickel); Explosive – TNT; Primer M32 – Black powder (sulfur, potassium nitrate, charcoal), primer mixture (mercury fulminate, potassium chlorate, antimony sulfide); Propellant – double-base powder (nitrocellulose and nitroglycerin); Ignition cartridge – double-base powder (nitrocellulose and nitroglycerin): Fuze M52 – Mercury fulminate, lead azide, and tetryl.	TM 43-0001-28
Mortar, 60mm All remaining sub-ranges	M50/Practice	M50 practice: Steel (chromium, copper, iron, nickel); Spotting charge – black powder (sulfur, potassium nitrate, charcoal).	TM 43-0001-28
Projectile, 75mm All remaining sub-ranges	M48/HE w/ Propellant w/ Fuze M48 or M54	M48 HE: Steel (chromium, copper, iron, nickel); Explosive – TNT; Primer M32 – Black powder (sulfur, potassium nitrate, charcoal), primer mixture (mercury fulminate, potassium chlorate, antimony sulfide); Propellant – FNH powder (nitrocellulose, dibutylphthalate, dinitrotoluene, diphenylamine); Fuze M48 – Mercury fulminate, lead azide.	TM 43-0001-28
	M61/AP Practice w/tracer	M61 AP (practice): Steel (chromium, copper, iron, nickel); Propellant – FNH powder (nitrocellulose, dibutylphthalate, dinitrotoluene, diphenylamine); Tracer – Tracer composition: strontium nitrate, polyvinyl chloride, strontium peroxide, magnesium powder.	

Table 4-4 Composition of Munitions Potentially Used at the MRS (Continued)

Size/Type Sub-Range	Nomenclature	Munitions Constituent(s)	Reference
Mortar, 81mm All remaining sub-ranges	M43A1/HE Shell w/Primer M33 w/ Propellant w. Ignition Ctg w/ Fuze M52	M43A1 HE: Steel (chromium, copper, iron, nickel); Explosive – TNT; Primer M33 – Black powder (sulfur, potassium nitrate, charcoal), primer mixture (mercury fulminate, potassium chlorate, antimony sulfide); Propellant – double-base powder (nitrocellulose and nitroglycerin); Ignition cartridge – double-base powder (nitrocellulose and nitroglycerin); Fuze M52– Mercury fulminate, lead azide, and tetryl.	TM 43-0001-28
	M44/Practice	M44 Practice: Steel (chromium, copper, iron, nickel); Spotting charge – Black powder (sulfur, potassium nitrate, charcoal).	
	M57/WP Smoke	M57 WP: White phosphorus; Steel (chromium, copper, iron, nickel); Propellant – double-base powder (nitrocellulose and nitroglycerin).	
Grenade, Rifle All remaining sub-ranges	M9A1 AT (rifle)	Explosive – TNT;	Various Sources
Mines, AP All remaining sub-ranges	M8/Practice w/ Fuze, M10A1	M8 Practice: Steel (chromium, copper, iron, nickel); Spotting charge – Black powder (sulfur, potassium nitrate, charcoal), red phosphorus.	TM 43-0001-36
Mines, AT All remaining sub-ranges	M1/Practice w/ Fuze, M1	M1 Practice: Steel (chromium, copper, iron, nickel); Spotting charge – Black powder (sulfur, potassium nitrate, charcoal), red phosphorus.	TM 43-0001-36
Rocket, 2.36” Bazooka All remaining sub-ranges	M7/Practice	Steel (chromium, copper, iron, nickel); spotting charge – Black powder (sulfur, potassium nitrate, charcoal),	Various Sources
	M6/HEAT w/ Propellant	Explosive Pentolite – TNT and Pentaerythritol tetranitrate; M7 powder.	

Notes:
AP – Armor Piercing
HE – High Explosive
mm - millimeter
TNT - trinitrotoluene

The analytical methods selected to address munitions-related chemical contaminants were based on the types of items known or suspected to exist at the MRS and the associated MC (see **Table 4-4**).

The potential MC at the MRS included energetics (nitroaromatics, nitramines, and nitrate esters) and lead. Energetics were intended to be analyzed following USEPA SW-846 Method 8330B (mod), (USEPA, 2006) and lead following USEPA SW-846 Method 6010C (USEPA, 2007). Method 8330B is referred to as modified because, although all of the laboratory requirements for implementing SW-846 Method 8330B were to be conducted (e.g., air drying, sub-sampling, etc.), incremental sampling techniques were not incorporated into the RI Work Plan (HDR, 2013). The specific chemicals of concern are listed below in **Table 4-5**.

Propellants from any MC at the MRS would be in the form of single base (artillery), double base (small arms, mortar), or triple base (howitzer) compositions that consist mainly of nitrocellulose (NC) impregnated with 2,4-dinitrotoluene (2,4-DNT single-base), nitroglycerin (NG double-base), or NC and nitroguanidine (NQ triple-base). Residues are usually deposited at the firing points as partially burned particles of the solid propellant and the heterogeneity is much smaller than that for explosives at impact sites. NC has no known health or environmental risks and is usually not a chemical of concern or an analyte listed for analysis. The commercial availability and analytical methods for the analysis of NC and NG is either non-existent or as a specialty item. 2,4-DNT and NC are part of the analyte list for Method 8330 because they are also explosive chemicals used as an energetic. Stabilizers (dibutylphthalate and diphenylamine) are used in some propellants formulations and are usually 5-25% of the entire composition. The presence and concentration of these stabilizers at a specific site depend highly on the age of the site and are directly proportional to the amount of activity at the site for that particular munition. Other than the munitions recovered during the prior clearance efforts (e.g., M51 37mm and M63 HE 37mm projectiles and frag from 81mm mortars), there is no definitive evidence that these munitions were used at the MRS, and the stabilizer analytes associated with them would be negligible (USEPA, 2012), (USACE, 2011). Therefore, propellants were not considered during the RI field investigation.

Table 4-5 Analyte List – Port Angeles Combat Range

Lead – USEPA SW-846 Method 6010C
Lead
Explosives – USEPA SW-846 Method 8330B (modified)
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)
1,3,5-Trinitrobenzene (1,3,5-TNB)
1,3-Dinitrobenzene (1,3-DNB)
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)
Nitrobenzene (NB)
3,5-Dinitroaniline
2,4,6-Trinitrotoluene (2,4,6-TNT)
4-Amino-2,6-dinitrotoluene (4-Am-DNT)
2-Amino-4,6-dinitrotoluene (2-Am-DNT)
2,4-Dinitrotoluene (2,4-DNT)
2,6-Dinitrotoluene (2,6-DNT)
2-Nitrotoluene (2-NT)
3-Nitrotoluene (3-NT)
4-Nitrotoluene (4-NT)
Pentaerythritol tetranitrate (PETN)
Nitroglycerin

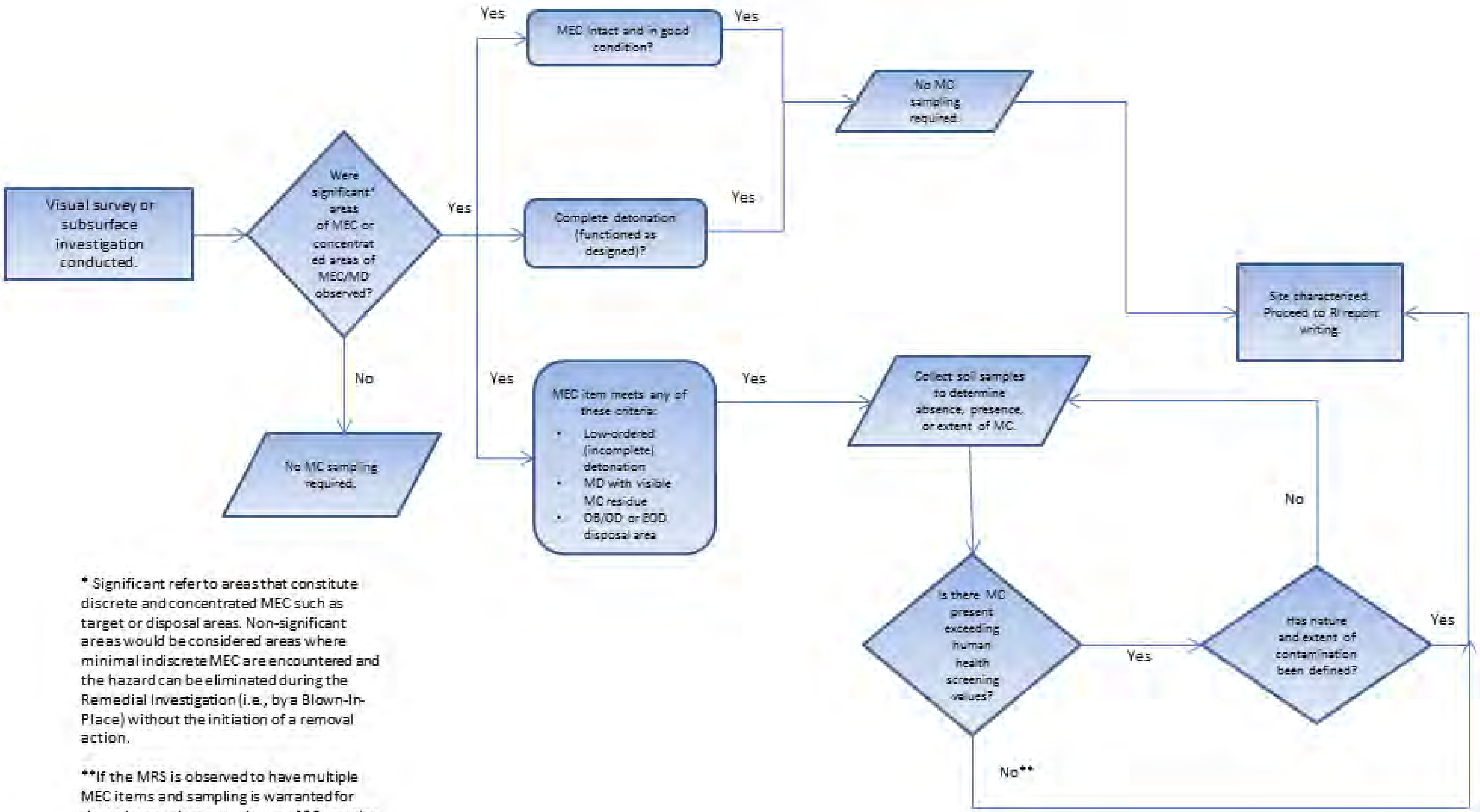
4.2.1.1 MUNITIONS CONSTITUENTS ENERGETICS SAMPLING – SOIL

If concentrations of MEC were sufficient to cause a possible release at the MRS, discrete grab samples for energetics would have been taken and sent to an off-site laboratory for analysis. If there was no significant source (MEC) observed within the MRS, no sampling would be conducted. There were six general situations that could have been encountered during field operations that were evaluated to determine if MC sampling for energetics was required if a MEC item was found as follows:

1. Intact, good condition MEC item – MC sampling was not performed because a release would not have occurred. The UXO team would have disposed of the item.
2. Intact, poor condition MEC item – MC sampling would be performed if an immediate explosive hazard was not present. If an immediate explosive hazard existed, the UXO team would have disposed of the item. MC sampling would have occurred after the disposal operations.
3. A low-ordered (incomplete detonation) MEC item – MC sampling would have been performed if an immediate explosive hazard had not been present. If an immediate explosive hazard existed, the UXO team would have disposed of the item. MC sampling would have occurred after the disposal operations.
4. Munitions debris with visible MC residue – MC sampling would have been performed if an immediate explosive hazard had not been present. If an immediate explosive hazard existed, the UXO team would have disposed of the item. MC sampling would have occurred after the disposal operations.
5. Munitions that have functioned as designed (complete detonation) – MC sampling would not occur because all explosives associated with the munitions would have been consumed during detonation.
6. Open Burn/Open Detonation – MC sampling would have been performed if an immediate explosive hazard was not present.

As described in the first and fifth scenarios above, all MEC and MD found at the MRS during the RI were intact, in good condition, or functioned as designed (complete detonation). MC sampling for energetics was not performed because a MC release would not have occurred. **Figure 4-7** presents the decision logic for conducting MC sampling at the MRS.

Figure 4-7 Decision Logic for Munitions Constituent Sampling for Explosives



* Significant refer to areas that constitute discrete and concentrated MEC such as target or disposal areas. Non-significant areas would be considered areas where minimal indiscrete MEC are encountered and the hazard can be eliminated during the Remedial Investigation (i.e., by a Blown-In-Place) without the initiation of a removal action.

**If the MRS is observed to have multiple MEC items and sampling is warranted for these items, then a maximum of 20 samples will be collected that are geographically dispersed throughout the MRS. Once analyzed for energetics and the results indicate concentrations below the screening levels, then MC sampling will no longer be required for the MRS.

4.2.1.2 MUNITIONS CONSTITUENTS LEAD SAMPLING – SOIL

MC sampling for small arms was included in the RI Work Plan (HDR, 2013) based on the Interstate Technology and Regulatory Council (ITRC) guidance (ITRC, 2003). Lead in a small arms projectile makes up more than 85% of its total weight and is the indicator for all other small arms projectile constituents. Since lead constitutes the greatest environmental concern as documented impacts to human health indicate, and because it is known that lead projectile fragments create dust upon impact at the berm and vapor upon heat of ignition at the firing line, lead in soil was utilized to determine nature and extent within the Range Complex No. 1 MRS for all other metals

In-situ XRF screening was conducted to analyze for lead in soils where natural features (e.g., natural berm feature) or small arms debris was identified. In-situ XRF screening was utilized for information only and to assist the field investigation team determine sampling locations for potential laboratory analysis. Since there could possibly be matrix interference due to the soil moisture content potentially being greater than 20%, per USEPA Method 6200, a conservative in-situ XRF screening level of 125 mg/kg (compared to the State of Washington soil cleanup level of 250 mg/kg) was utilized to evaluate lead concentrations in soils.

In-situ XRF screening measurements were recorded and geo-referenced only to provide information to the field investigation team to collect potential samples for laboratory analysis. The locations were also utilized to document the absence of lead in natural berm like features if there is no evidence of small arms use.

Below are the two general situations that were encountered during field operations that were evaluated to determine if lead sampling and laboratory analysis was required:

1. Small arms debris (casings, projectiles) observed in an area
2. Natural features such as a berm or slope indicating a potential impact zone of a small arms range

If the decision was made that soil sampling was necessary or warranted, discrete surface and subsurface soil samples for lead would have been collected and sent to an analytical laboratory for analysis, per the procedures outlined in the RI Work Plan (HDR, 2013). Sample collection was planned to continue horizontally and vertically until the analytical results were below the WDOE soil cleanup level for Washington Model Toxics Act Soil Cleanup Level under Method A for unrestricted future land use at 250 mg/kg.

4.2.1.3 ENVIRONMENTAL MEDIA SAMPLING – SURFACE WATER AND SEDIMENT

The decision logic to collect sediment and surface water samples was the same as that for soil sampling and was based on the presence of compromised MEC or observed small arms debris.

4.2.1.4 ENVIRONMENTAL MEDIA SAMPLING – GROUNDWATER

No groundwater sampling was anticipated at the MRS based on the groundwater sampling conducted as part of the SI in 2009. All MC concentrations were reported as non-detects in the SI (Shaw, 2009).

During the RI field investigation, field teams noted evidence of seeps, springs, and surface to groundwater communication (i.e., hydrogeological connections).

4.2.1.5 DECONTAMINATION REQUIREMENTS

Decontamination requirements were included in the RI Work Plan (HDR, 2013). Minimal decontamination was required during the RI. Disposable equipment, which did not require decontamination, was used whenever possible. Dry decontamination was performed on reusable sampling and non-sampling equipment to prevent cross-contamination between sampling locations. Stainless steel equipment and testing equipment (e.g., XRF analyzer) were decontaminated in the field by utilizing the dry decontamination method. First, a nylon brush was used to remove any residual soil on the equipment. Disposable hand wipes and paper toweling were then used to clean remaining soil deposits from the stainless steel and testing equipment. All decontamination materials and used personal protective equipment (PPE) were placed into a re-sealable plastic bag and disposed of in a non-hazardous waste municipal dumpster at the conclusion of sampling activities.

4.2.1.6 DATA REVIEW AND VALIDATION

In order to determine the overall usability of proposed analytical laboratory results, data review and validation requirements were also included in the RI Work Plan (HDR, 2013). The Project Chemist was available to review all analytical laboratory data against project specific DQOs and the *DoD Quality Systems Manual (QSM) Environmental Laboratories, Final Version 4.2* (DoD, 2010). The method-specific criteria followed *USEPA Office of Solid Waste and Emergency Response Test Methods for Evaluating Solid Waste Physical/Chemical Methods (SW-846), Update IV*B) (USEPA, 2008a) and the subcontract laboratory SOPs. Data validation was planned to be conducted in accordance with the *National Functional Guidelines for Inorganic Superfund Data Review* (USEPA, 2010) and the *National Functional Guidelines for Superfund Organic Methods Data Review* (USEPA, 2008b).

5.0 Revised Conceptual Site Model and Remedial Investigation Results

Field activities including AVS, geophysical surveys, subsurface investigations, and in-situ XRF screening for lead in soil were conducted as described in **Section 4.0**. The results and discussion of the nature and extent of MEC, MD, and MC contamination discovered are presented in the following subsections. A detailed analysis of the RI findings relative to the historical documentation and the Range Complex No. 1 MRS is presented in **Section 5.2.1.4**.

MEC and MC exposure pathways were evaluated based on the findings from the RI field investigations and updated from the RI Work Plan (HDR, 2013). For discussion in this RI/FS, Range Complex No. 1 MRS has been informally split into three MRSs based on different levels of risk for each area. These three MRSs reflect the information from historical investigation records, AVS, geophysical surveys, the subsurface investigation, and in-situ XRF screening for lead in soil performed during the RI. These MRSs were developed based on the types and distribution of MEC/MD within each MRS and their recommended remedial action alternatives. These are also the same MRSs evaluated in the MEC Hazard Assessment (MEC HA). **Section 8.5.1** summarizes the MRSs, which resulted in the creation of additional CSMs for access and exposure to MEC and MC for all receptors.

5.1 Munitions and Explosives of Concern

MEC investigation results from the AVS, geophysical surveys, and subsurface investigations are presented and evaluated in the following subsections.

5.1.1 MEC Investigation Results

5.1.1.1 ASSISTED VISUAL SURVEY RESULTS

Data were collected utilizing AVS during the RI at the PACR to document observations of surface MD as well as other features relevant to the CSM such as water features, nearby receptors, etc. Due to cliffs or steep slopes, the presence of extensive areas of streams and/or dense vegetation, 567.8 acres of the PACR were unsurveyable and inaccessible. No MEC was recovered during the AVS. A total of 112 miles of AVS transects were walked.

UXO personnel conducted AVS investigations with a Schonstedt magnetometer detector to locate and investigate subsurface anomalies. The depth of detection is limited by the size and orientation of the target and by soil characteristics. The Schonstedt instrument is not capable of classifying anomalies; it will only indicate the presence or absence of a subsurface anomaly. To ensure that the Schonstedt instruments were functioning properly, each instrument operator was required to walk the IVS using the sweep techniques and instrument settings proposed in the RI Work Plan (HDR, 2013), and detect 100% of the items at least once a day.

A total of three hundred and twelve (312) features were logged into Trimble GeoXH GPS units during the AVS. One hundred and thirty-four (134) features document unsurveyable terrain. Fourteen (14) features were non-military related items such as logging industry debris and civilian trash including; metal debris, metal cables, barbed wire, and old automobile wheel hubs.

During the AVS, the field investigation team observed only one MD item (an unidentifiable piece of HE frag) in grid R-01 (**Appendix C**). Initially, there was concern that there was an absence of MD in

Technical Approach Areas 1 and 3. However, the initial concerns were alleviated when all of the RI data were collected and the munitions related features corresponded with the location of the targets and impact areas identified in the ASR.

The AVSs that were performed in Technical Approach Area 2 were primarily reserved for anomaly avoidance and the identification of metallic features that would interfere with the DGM. While portions of the MRS were unsurveyable, the areas that were surveyed in combination with the other RI activities (e.g. analysis of historic information and line of sight modeling) were sufficient to meet the goals of the RI. The AVS proved to be an effective tool during the RI, as the AVS teams did identify subsurface MD and other metallic debris while assisting the DGM survey teams.

Appendix C presents the photograph documentation log showing the site features and unsurveyable terrain encountered during the AVS within the MRS. **Figure 5-1** through **Figure 5-3** show the location the AVS transects completed for each Technical Approach Area, parcels where a ROE could not be obtained and the extent of areas that were determined to be unsurveyable.

5.1.1.2 DIGITAL GEOPHYSICAL MAPPING RESULTS

DGM data were collected with an EM61-MK2 litter over a period of ten survey days from October 28, 2013 to November 12, 2013 in Technical Approach Area 2. A portion of Technical Approach Area 2 was surveyed along transects spaced 35-feet apart and the remainder of the accessible portions of Technical Approach Area 2 were surveyed along transects with 75-foot spacing. The 35-foot spaced transects were collected within the area that was historically an open meadow that contained artillery target features. The open meadow area was determined from a historical aerial photograph analysis. The historical photograph analysis utilized the dataset closest to the ranges post operational status (i.e., 1956).

Several acres were determined to be unsurveyable by DGM techniques due to the impassable vegetation, downed trees, slippery slopes, and other environmental hazards. Field Change Request (FCR) #2 (**Appendix E**) was submitted requesting that this unsurveyable acreage be completed utilizing AVS with real time excavation techniques to fill the data gaps. FCR #2 was approved by the USACE during the DGM field investigation.

After the first day of data collection, the DGM data were analyzed to calculate the noise threshold used for target picking. Four transect subsections were picked out that appeared to exhibit typical EM61-MK2 background noise by the data processor. Noise and target picking threshold of 12 mV, sum channel, was calculated using the formula described in **Section 4.1.2.4**. The geophysical field team collected at total of 17.6 miles DGM data shown on **Figure 5-4**. Targets were picked over data that had acceptable GPS data quality and exhibited proper decay. In total 3,123 targets were picked automatically by Geosoft Oasis montaj Version 8.0.1 (**Figure 5-5**). The four control points surveyed with the litter produced geophysical anomalies that validated the positional accuracy of the DGM data and the accuracy of the control point coordinates measured by the Washington State licensed land surveyor (**Figure 4-4**).

The USACE was briefed on the results of the DGM investigation and approved the results of the DGM prior to demobilization. The areas containing greater than 250 geophysical anomalies per acre were also investigated as described below. The project geophysicist certifies that all established DQOs were met and that the DGM data is useable for its intended purposes.

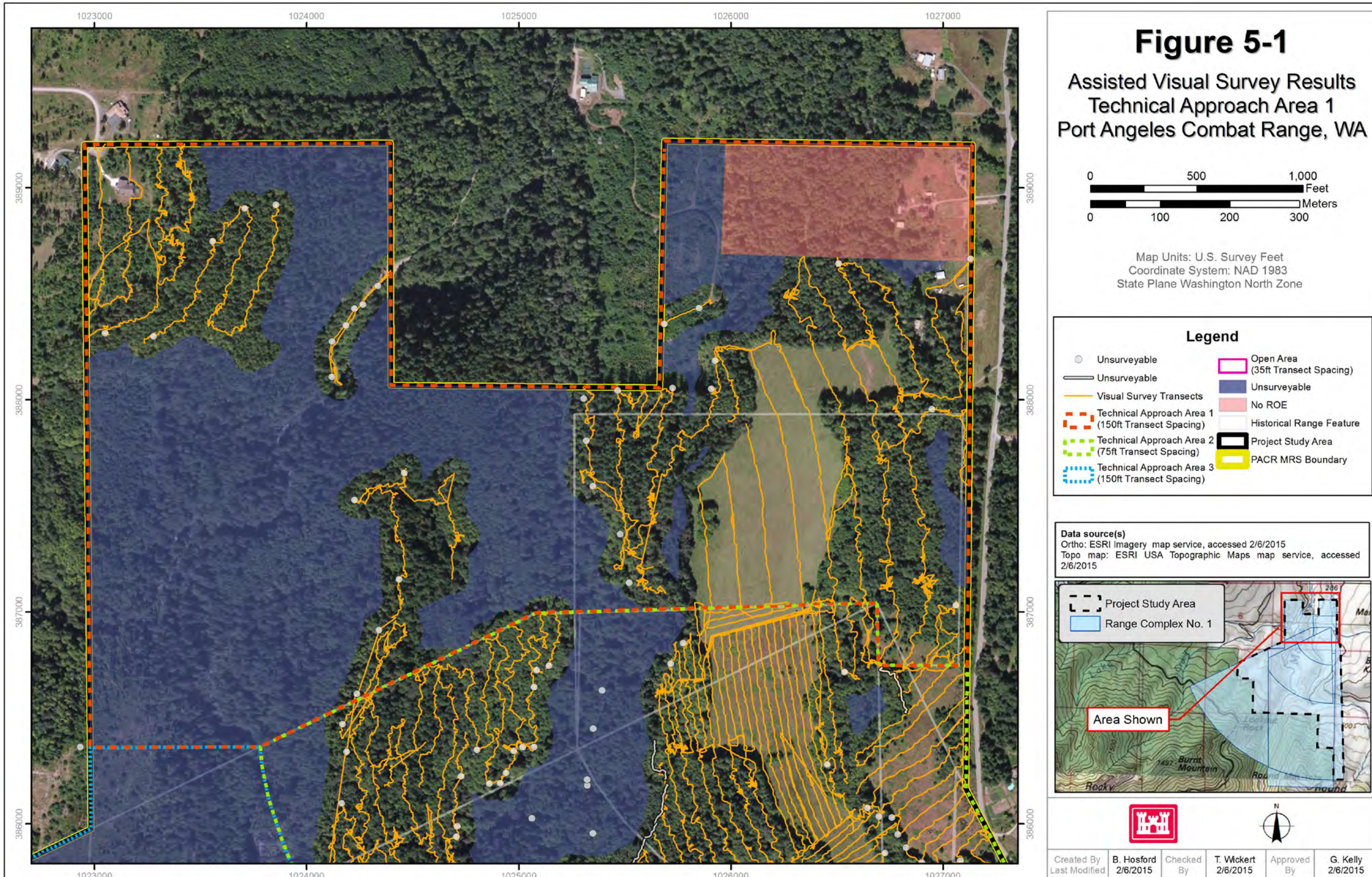


Figure 5-1
Assisted Visual Survey Results
Technical Approach Area 1
Port Angeles Combat Range, WA
0 500 1,000 Feet
0 100 200 300 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
Unsurveyable
Unsurveyable
Visual Survey Transects
Technical Approach Area 1 (150ft Transect Spacing)
Technical Approach Area 2 (75ft Transect Spacing)
Technical Approach Area 3 (150ft Transect Spacing)
Open Area (35ft Transect Spacing)
Unsurveyable
No ROE
Historical Range Feature
Project Study Area
PACR MRS Boundary
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Project Study Area
Range Complex No. 1
Area Shown
Created By Last Modified B. Hosford 2/6/2015
Checked By T. Wickert 2/6/2015
Approved By G. Kelly 2/6/2015
1023000
1024000
1025000
1026000
1027000
389000
388000
387000
386000

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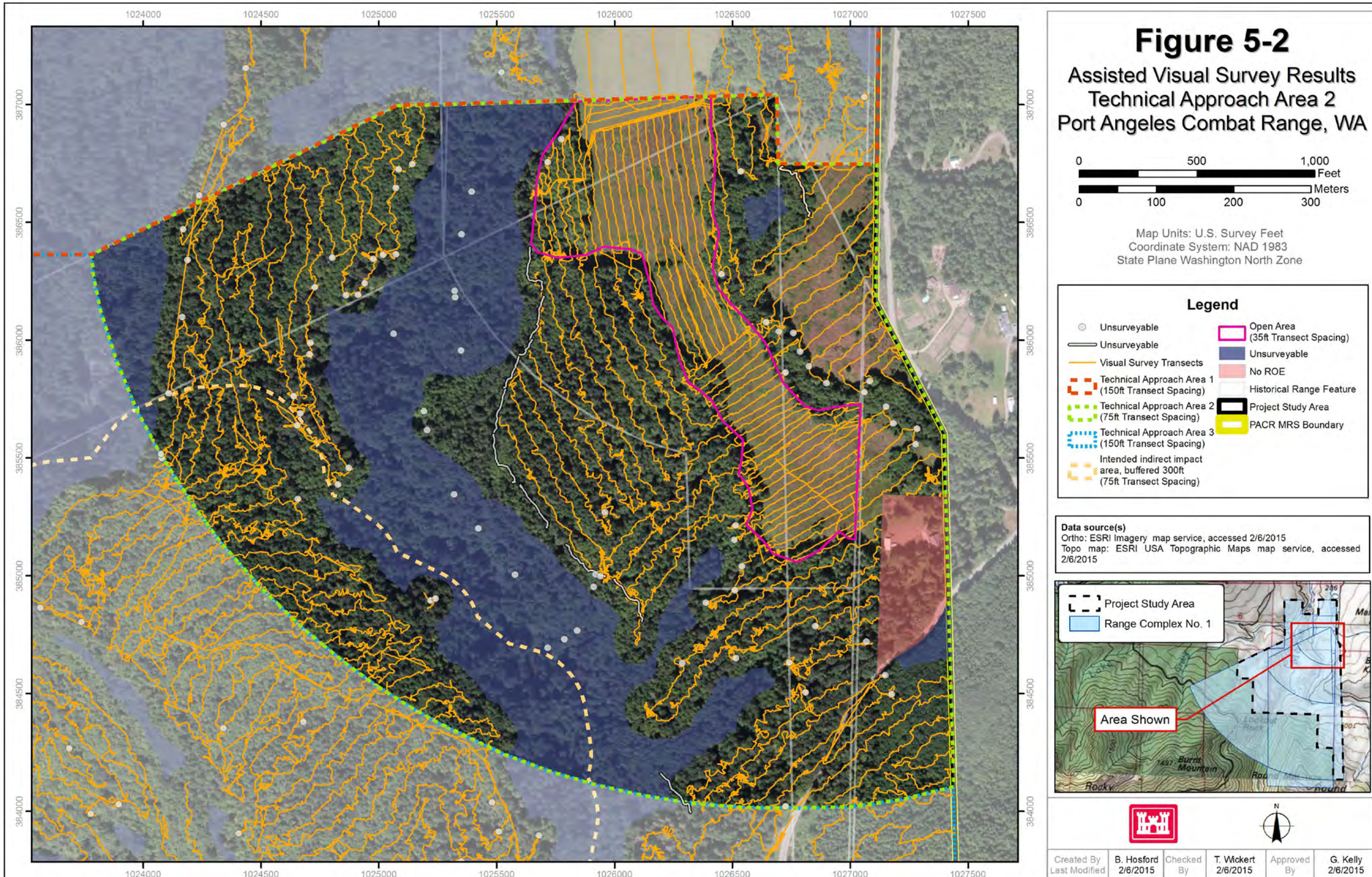
Figure 5-2
Assisted Visual Survey Results
Technical Approach Area 2
Port Angeles Combat Range, WA
0 500 1,000 Feet
0 100 200 300 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
Unsurveyable
Unsurveyable
Visual Survey Transects
Technical Approach Area 1 (150ft Transect Spacing)
Technical Approach Area 2 (75ft Transect Spacing)
Technical Approach Area 3 (150ft Transect Spacing)
Intended indirect impact area, buffered 300ft (75ft Transect Spacing)
Open Area (35ft Transect Spacing)
Unsurveyable
No ROE
Historical Range Feature
Project Study Area
PACR MRS Boundary
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Project Study Area
Range Complex No. 1
Area Shown
Created By Last Modified
B. Hosford 2/6/2015
Checked By
T. Wickert 2/6/2015
Approved By
G. Kelly 2/6/2015

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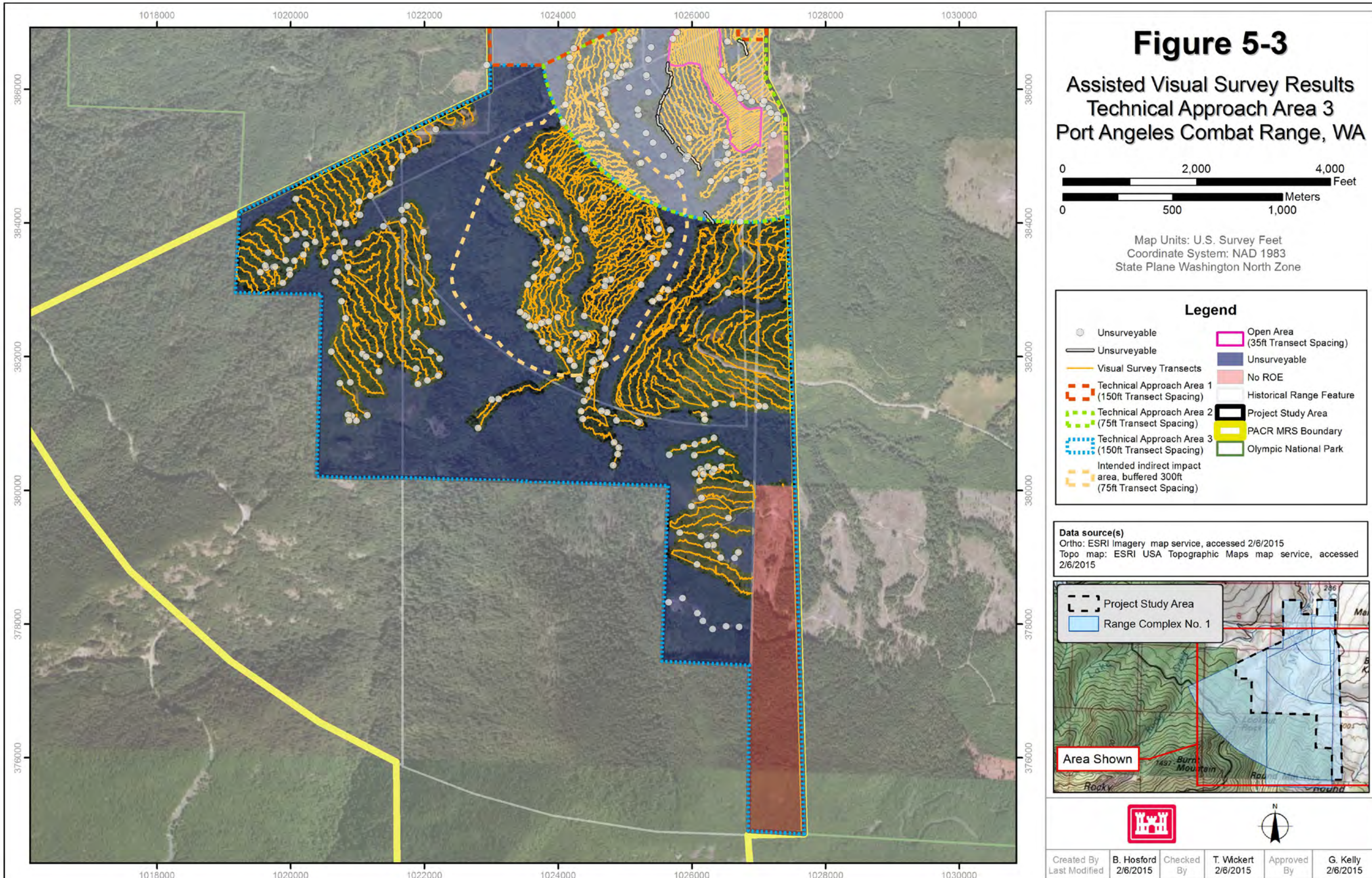
Figure 5-3
Assisted Visual Survey Results
Technical Approach Area 3
Port Angeles Combat Range, WA
0 2,000 4,000 Feet
0 500 1,000 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
Unsurveyable
Unsurveyable
Visual Survey Transects
Technical Approach Area 1 (150ft Transect Spacing)
Technical Approach Area 2 (75ft Transect Spacing)
Technical Approach Area 3 (150ft Transect Spacing)
Intended indirect impact area, buffered 300ft (75ft Transect Spacing)
Open Area (35ft Transect Spacing)
Unsurveyable
No ROE
Historical Range Feature
Project Study Area
PACR MRS Boundary
Olympic National Park
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Project Study Area
Range Complex No. 1
Area Shown
Created By Last Modified
B. Hosford 2/6/2015
Checked By
T. Wickert 2/6/2015
Approved By
G. Kelly 2/6/2015
1018000
1020000
1022000
1024000
1026000
1028000
1030000
386000
384000
382000
380000
378000
376000

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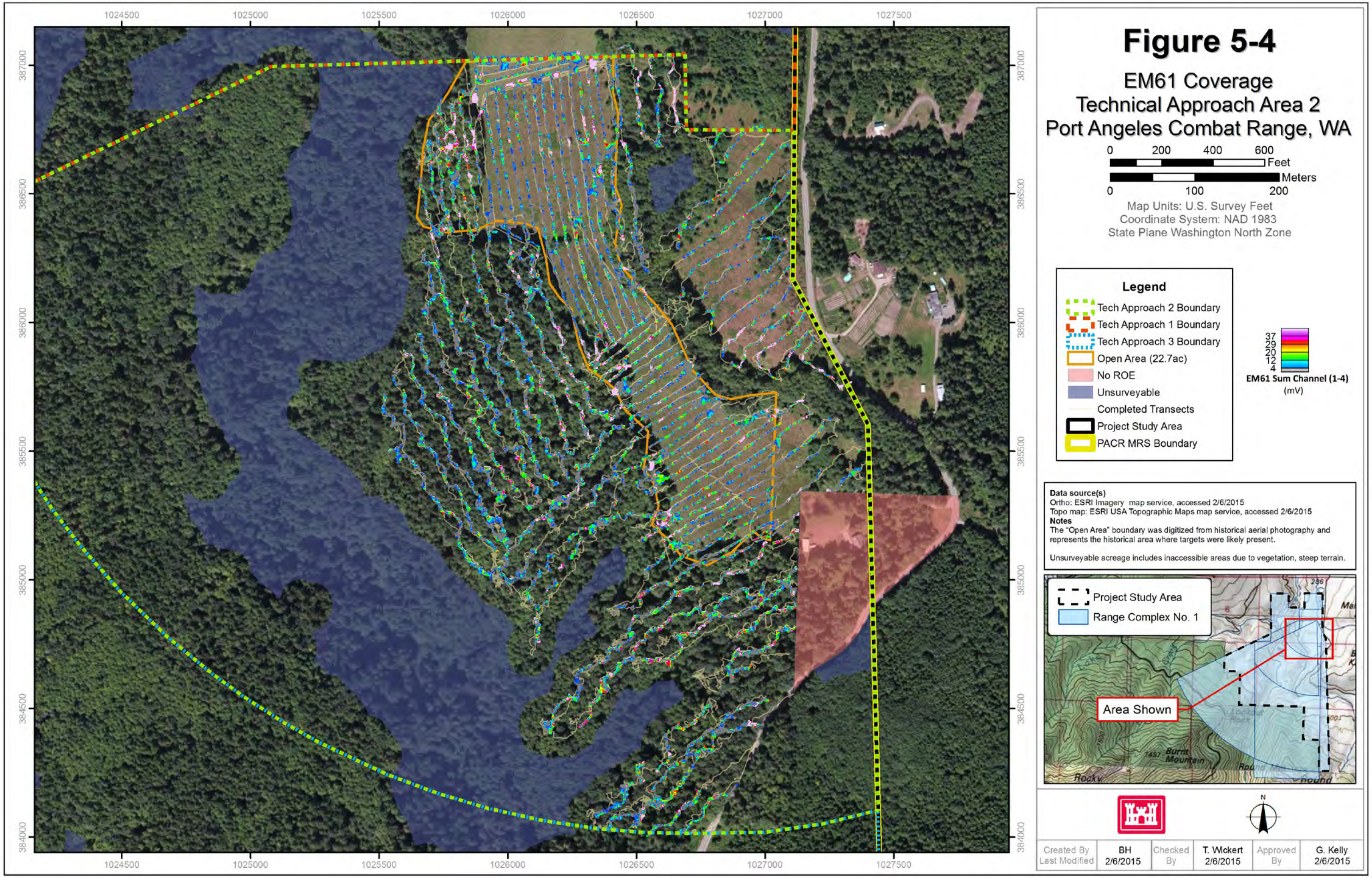
Figure 5-4
EM61 Coverage
Technical Approach Area 2
Port Angeles Combat Range, WA
0 200 400 600 Feet
0 100 200 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
Tech Approach 2 Boundary
Tech Approach 1 Boundary
Tech Approach 3 Boundary
Open Area (22.7ac)
No ROE
Unsurveyable
Completed Transects
Project Study Area
PACR MRS Boundary
37
29
20
12
4
EM61 Sum Channel (1-4)
(mV)
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Notes
The "Open Area" boundary was digitized from historical aerial photography and represents the historical area where targets were likely present.
Unsurveyable acreage includes inaccessible areas due to vegetation, steep terrain.
Project Study Area
Range Complex No. 1
Area Shown
Created By Last Modified
BH 2/6/2015
Checked By
T. Wickert 2/6/2015
Approved By
G. Kelly 2/6/2015
1024500
1025000
1025500
1026000
1026500
1027000
1027500
387000
386500
386000
385500
385000
384500
384000

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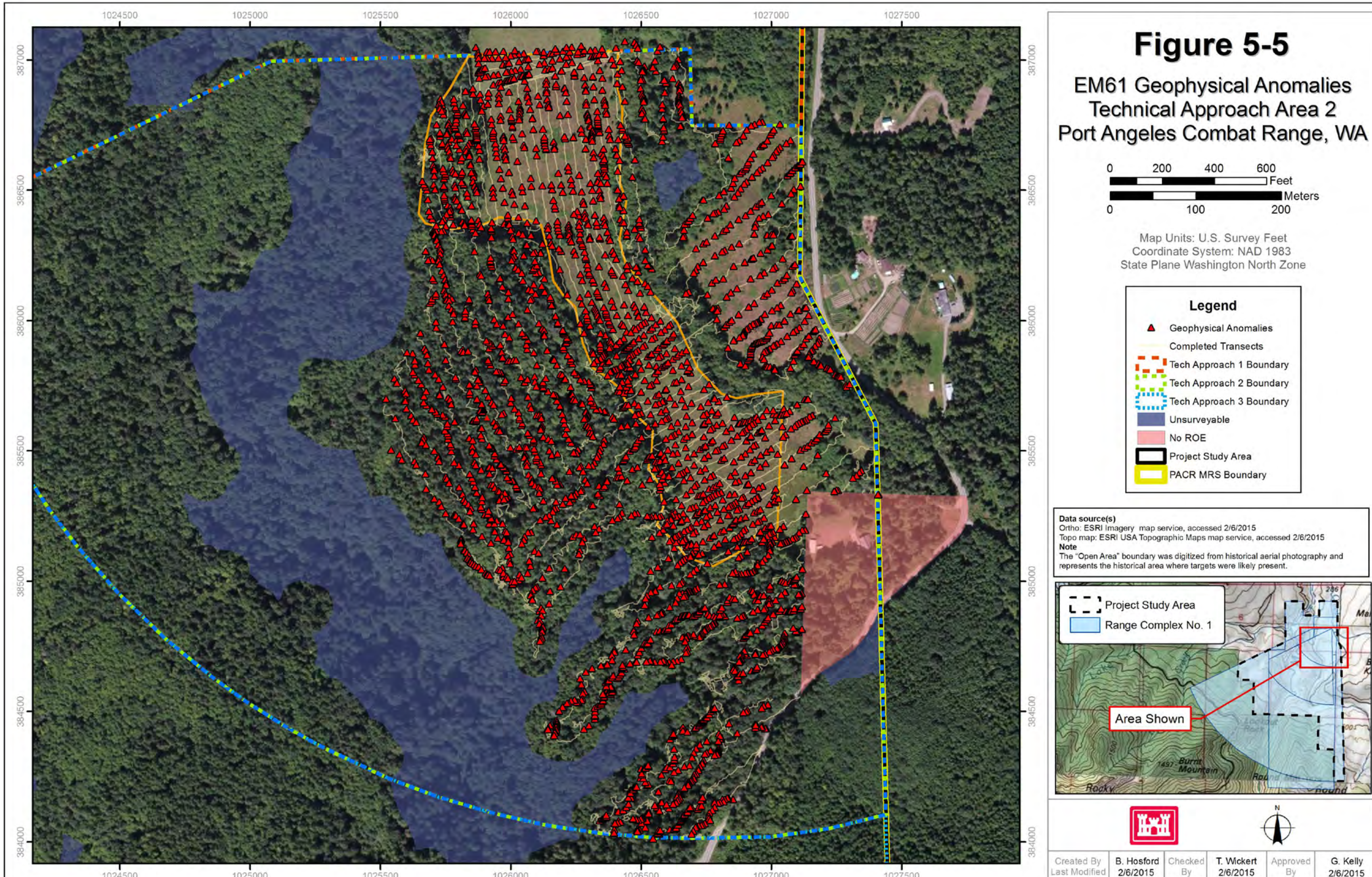

Figure 5-5
EM61 Geophysical Anomalies
Technical Approach Area 2
Port Angeles Combat Range, WA

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5.1.1.3 SUBSURFACE INVESTIGATION RESULTS

Prior to the subsurface investigation, anomaly densities were computed for each 200-foot x 200-foot grid. Density analysis of the geophysical anomaly dataset was performed using a weighted KDE analysis utilizing the ESRI Spatial Analyst toolbox. This process is commonly used to generate a probability density function for point datasets. An initial KDE raster was generated over the entire survey footprint utilizing the anomaly from the DGM process. The initial KDE raster was weighted to account for coverage bias. This was done by buffering the central GPS course-over-ground data to model the actual sensor footprint. Footprints were assumed to be one-meter across for the litter (**Figure 5-6**).

Percent coverage was determined for each one-meter kernel location in the KDE by creating a regularly spaced dense grid of points. These points were selected and retained where they intersected the actual transect swath from the survey. A KDE was then performed on the selected points and the output was normalized to values between zero, (no coverage) and one (100% coverage). This value was then applied to the original density calculation to provide final estimates of actual target densities throughout the DGM survey area. Density values were then applied to individual grids by assigning the mean anomaly density calculated within the grid extent (**Figure 5-7**). Based on the anomaly density analysis 119 grids were selected for subsurface investigation.

A subsurface investigation using hand-held analog geophysical instruments was conducted in Technical Approach Area 2 as described in **Section 4.1.4**. The objective of the subsurface investigation was to determine the nature and extent of subsurface MEC and MD. A grid system was established within the MRS at the completion of the DGM survey. The grid system was generally centered over Technical Approach Area 2. Grids of approximately 1-acre (200-foot x 200-foot) were established (**Figure 5-8**). The corners of each grid were temporarily established utilizing a Trimble GeoXH GPS unit. The results of the DGM survey were utilized to determine which grids were initially selected for the subsurface investigation. Anomaly densities were computed for each grid; grids having an anomaly density greater than 250 per acre were selected.

In addition to the original 119 grids, five grids were investigated as step-out grids. Step-out grids were established until the extent of munitions debris was determined. Complete delineation utilizing this methodology was achieved with the exception of grid S-05. No step-out investigations were conducted to the east of Deer Park Road, as an ROE was not obtained by the USACE for parcels 47420 and 47384. Grid S-05 contained three small pieces of MD weighing less than 0.25 lbs and is located just west of a road and the location of the old school house that was described in the ASR. Numerous interviews in the ASR indicated that firing had taken place on the west side of the road and that the direction of fire had been to the south/southwest (USACE, 1996). Based on typical and historic range usage it is unlikely that munitions were fired towards the old school house described in the ASR or across the only access road to the MRS. Because of the range configuration and the limited amounts of MD, the extent of potential MEC and MD is presumed to be to the western edge of Deer Park Road.

Approximately 10% of each grid was investigated and items were recorded as described in **Section 4.1.4**. The typical field layout for the sweep lanes within the grids is illustrated in **Figure 4-5**.

The subsurface investigation teams recorded any items that were classified as MEC, MD, small arms, and trash. Identifiable MD items (i.e., expended mortar body) and MEC were recorded individually. **Table 5-1** summarizes the MEC, identifiable MD, small arms, and trash recorded during the subsurface investigations. Weights of the recovered MEC, MD and small arms debris items were measured utilizing a hand held spring scale. Since the trash observed was not managed, the weights for the trash were estimated by visual observation. The subsurface investigation summary for each grid is displayed in **Figure 5-9**. The composition of munitions recovered during the subsurface investigation are presented in **Table 5-2; Appendix C** presents the photograph documentation log showing the MEC and MD features. Ordnance technical data sheets for the munitions recovered are presented in **Appendix H**.

One-hundred and forty-seven MD features were recovered during the subsurface investigation. Identifiable MD included:

- Thirteen M51 37mm Armor Piercing (AP) projectiles
- One M48 75mm projectile point detonating fuze (expended)
- One M44 81mm practice mortar
- Three M43A1 81mm HE mortar pieces
- Three M57 81mm WP mortar bodies
- Four 81mm mortar tail fin pieces
- One 81mm motor tail fin
- One 75mm practice projectile, and one half of 75mm projectile (empty)

Twenty-five small arms debris features (twenty unfired .50 caliber projectiles and five links) were recorded. Due to the presence of the .50 caliber links and the lack of rifling striations it is believed the small arms were likely unfired and deposited in the area, as there are no indications of a separate small arms impact area. If small arms were used at the PACR they were likely fired at the artillery and mortar targets.

Five MEC items were found during the RI field activities (**Figure 5-10**). Four MEC items were discovered in grid K-03 and one MEC item within grid M-11. All five MEC items were M63 37mm HE projectiles. All of these features were found in the Direct Fire Impact Area and the Buffer Zone and Combat Training Area (sub-ranges SR-01 and SR-05). These locations are consistent with the historical documentation available that indicated that the firing point was located in the northeast of the MRS, the direction of fire was south/southwest, and that the entire area was used extensively for training and maneuvers.

The first four M63 37mm HE projectiles were destroyed in consolidated disposal operations within grid Q-09. The fifth M63 37mm HE projectile was destroyed separately in a nearby location within grid Q-09.

In addition, as discussed in **Section 2.4.9,** on September 29, 2011, during an ESTCP geophysical survey, a UXO technician found a 37mm projectile as depicted on **Figure 2-9**. The UXO technician immediately notified the Clallam County Sheriff's office. A Washington State Police bomb technician safely disposed of the item explosively on September 29, 2011 (ESTCP, 2011).

Table 5-1 MEC, Munitions Debris, Small Arms, and Trash Recovered per Grid

Grid	Number of MEC Items	Number of MD Items	Description	Number of Small Arms Debris Items	Estimated weight (lbs) of MEC/MD/SA	Number of Trash Items	Estimated weight (lbs) of Trash
I-08	0	1	1 piece of HE frag	0	0.25	1	0.5
J-07	0	0		0	0	1	1
J-08	0	1	1 piece of HE frag	0	0.25	0	0
J-09	0	0		0	0	0	0
K-02	0	0		0	0	17	42
K-03	4 M63 37mm HE projectiles	8	8 pieces of HE frag	2 .50 caliber projectiles	10	9	18
K-04	0	10	1 M51 37mm AP projectile and 9 pieces of HE frag	5 .50 caliber projectiles	1.5	8	19
K-05	0	0		0	0	25	70
K-06	0	1	1 piece of HE frag	0	0.25	4	40
K-07	0	1	1 piece of HE frag	0	0.25	0	0
K-08	0	2	1 piece of HE frag	0	0.25	2	10
K-09	0	1	1 piece of HE frag	0	0.25	1	0.25
K-10	0	0		0	0	5	3
L-00	0	0		0	0	13	3
L-01	0	0		0	0	6	3
L-02	0	3	3 pieces of HE frag	0	0.5	14	22
L-03	0	12	1 M57 81mm WP mortar body and 11 pieces of HE frag	6 .50 caliber projectiles	1	10	16
L-04	0	10	1 M57 37mm AP projectile, 9 pieces of HE frag	7 .50 caliber projectiles and 5 links	4	0	0
L-05	0	3	1 M51 37mm AP projectile and 2 pieces of HE frag	0	1	10	10
L-07	0	0		0	0	0	0
L-08	0	0		0	0	0	0
L-09	0	6	2 M51 37mm projectiles and 4 pieces of HE frag	0	4.75	0	0
L-10	0	1	1 piece of HE frag	0	0.25	1	5
L-11	0	0		0	0	1	0.25
M-00	0	0		0	0	14	8
M-01	0	2	1 M51 37mm AP projectile and 1 piece of HE frag	0	1	0	1

Table 5-1 MEC, Munitions Debris, Small Arms, and Trash Recovered per Grid (Continued)

Grid	Number of MEC Items	Number of MD Items	Description	Number of Small Arms Debris Items	Estimated weight (lbs) of MEC/MD/SA	Number of Trash Items	Estimated weight (lbs) of Trash
M-02	0	0		0	0	7	2
M-03	0	3	1 M44 81mm practice mortar and 2 pieces of HE frag	0	5	4	6
M-04	0	4	1 81mm mortar tail fin piece and 3 pieces of HE frag	0	0.5	0	0
M-05	0	0		0	0	100	5
M-06	0	2	1 M57 81mm WP mortar body and 1 piece of HE frag	0	3	4	3
M-07	0	3	3 pieces of HE frag	0	0.25	3	1
M-08	0	2	1 M51 37mm projectile and 1 piece of HE frag	0	1.25	5	0.5
M-09	0	1	1 piece of HE frag	0	0.25	0	0
M-10	0	2	2 pieces of HE frag	0	0.25	0	0
M-11	1 M63 37mm HE projectile	0		0	1	5	5
M-12	0	0		0	0	6	25
N-01	0	0		0	0	7	10
N-00	0	0		0	0	3	2
N-02	0	0		0	0	5	3
N-03	0	5	1 M51 37mm AP projectile and 4 pieces of frag	0	2	0	0
N-04	0	3	1 M51 37mm AP projectile, 1 81mm mortar tail fin piece, and 1 M43A1 81mm HE mortar base	0	4.5	0	0
N-05	0	1	1 piece of HE frag	0	0.25	0	0
N-06	0	1	1 piece of HE frag	0	0.25	0	0
N-07	0	1	1 M51 37mm AP projectile	0	1.5	3	8
N-08	0	4	2 M43A1 81mm HE mortar pieces and 2 pieces of HE frag	0	2	4	0.5
N-09	0	1	1 M51 37mm AP projectile	0	1	2	1
N-10	0	0		0	0	0	0
N-11	0	0		0	0	2	3.5
N-12	0	1	1 75mm practice projectile	0	10	11	300
N-13	0	0		0	0	0	0
N-14	0	0		0	0	1	1

Table 5-1 MEC, Munitions Debris, Small Arms, and Trash Recovered per Grid (Continued)

Grid	Number of MEC Items	Number of MD Items	Description	Number of Small Arms Debris Items	Estimated weight (lbs) of MEC/MD/SA	Number of Trash Items	Estimated weight (lbs) of Trash
N-15	0	0		0	0	2	25
N-16	0	0		0	0	0	0
P-01	0	0		0	0	15	10
P-02	0	1	1 piece of HE frag	0	0.25	75	83
P-03	0	1	1 81mm mortar tail fin	0	0.5	14	1
P-04	0	2	1 M51 37mm AP projectile and 1 piece of HE frag	0	1.25	1	0.25
P-05	0	0		0	0	12	60
P-06	0	0		0	0	1	10
P-07	0	1	1 piece of HE frag	0	0.25	0	0
P-08	0	1	1 M57 81mm WP mortar body	0	0.5	13	5
P-09	0	0		0	0	4	2
P-10	0	2	2 piece of HE frag	0	0.25	1	0.25
P-11	0	0		0	0	0	0
P-12	0	1	1 M51 37mm AP projectile	0	1	2	40
P-13	0	0		0	0	0	0
P-14	0	0		0	0	2	2
P-15	0	0		0	0	0	0
P-16	0	1	1 M48 point detonating fuze (expended)	0	1	0	0
Q-01	0	0		0	0	62	30
Q-02	0	2	2 81mm mortar tail fin pieces	0	0.25	11	0.5
Q-03	0	0		0	0	13	30
Q-04	0	0		0	0	10	15
Q-05	0	0		0	0	6	15
Q-06	0	0		0	0	7	20
Q-07	0	1	1 piece of HE frag	0	0.25	0	4
Q-08	0	0		0	0	4	1
Q-09	0	0		0	0	1	3
Q-10	0	8	8 pieces of HE frag	0	1	3	1
Q-11	0	14	14 pieces of frag	0	1	10	4
Q-12	0	2	1 half of 75mm projectile (empty) and 1 piece of HE frag	0	5.25	1	0.25
Q-13	0	0		0	0	3	1
Q-14	0	0		0	0	2	1
Q-16	0	0		0	0	1	5
Q-17	0	0		0	0	1	0.25

Table 5-1 MEC, Munitions Debris, Small Arms, and Trash Recovered per Grid (Continued)

Grid	Number of MEC Items	Number of MD Items	Description	Number of Small Arms Debris Items	Estimated weight (lbs) of MEC/MD/SA	Number of Trash Items	Estimated weight (lbs) of Trash
R-01	0	1	1 piece of HE frag	0	0.25	6	5
R-02	0	0		0	0	1	1
R-03	0	1	1 piece of HE frag	0	0.25	5	2
R-04	0	0		0	0	5	6
R-05	0	0		0	0	1	1
R-06	0	0		0	0	0	0
R-07	0	0		0	0	12	30
R-08	0	0		0	0	3	30
R-09	0	2	2 pieces of HE frag	0	1	0	2
R-10	0	1	1 piece of HE frag	0	1	0	2
R-11	0	0		0	0	13	4
R-12	0	0		0	0	5	25
R-13	0	0		0	0	1	1
R-14	0	0		0	0	6	2
R-15	0	0		0	0	8	3
R-16	0	0		0	0	3	5
S-02	0	0		0	0	0	0
S-03	0	0		0	0	2	0.25
S-04	0	0		0	0	0	0
S-05	0	3	3 pieces of HE frag	0	0.25	0	0
S-06	0	0		0	0	1	0.25
S-07	0	1	1 piece of HE frag	0	0.25	3	10
S-08	0	0		0	0	112	311
S-09	0	0		0	0	3	17
S-10	0	0		0	0	2	3
S-11	0	1	1 piece of HE frag	0	0.5	3	2
S-12	0	2	2 pieces of HE frag	0	0.5	7	3
S-13	0	0		0	0	0	0
T-07	0	0		0	0	3	10
T-08	0	0		0	0	2	0.5
T-09	0	0		0	0	0	0
T-10	0	0		0	0	100	20
T-11	0	0		0	0	3	1
T-12	0	0		0	0	0	0
T-13	0	0		0	0	10	2
Total	**5**	**147**		**25**	**76.5**	**924**	**1523**

Table 5-2 Composition of Munitions Recovered during the Subsurface Investigation, Range Complex No. 1 MRS

Size/Type Sub-Range	Nomenclature	Munitions Constituent(s)	Reference
Ctg, .50 caliber R01-SR-01	M2/Ball	Lead; Propellant – single-base (nitrocellulose) or double-base (nitrocellulose and nitroglycerin).	TM 43-0001-27
Shell, 37mm All remaining sub-ranges	M/63 HE with fuze M58 w/ Primer w/ Propellant	M63 HE: Steel (chromium, copper, iron, nickel); Explosive – TNT: Fuze M58 – lead azide, tetryl; Primer M23 – Black powder (sulfur, potassium nitrate, charcoal), primer mixture (mercury fulminate, potassium chlorate, antimony sulfide).	TM 43-0001-28
	M51/TP w/Primer M23 w/Propellant	M51 TP: Steel (chromium, copper, iron, nickel); Primer M23 – primer mixture (mercury fulminate, potassium chlorate, antimony sulfide).	TM 9-1901
Mortar, 81mm All remaining sub-ranges	M43A1/HE Shell w/Primer M33 w/ Propellant w. Ignition Ctg w/ Fuze M52	M43A1 HE: Steel (chromium, copper, iron, nickel); Explosive – TNT; Primer M33 – Black powder (sulfur, potassium nitrate, charcoal), primer mixture (mercury fulminate, potassium chlorate, antimony sulfide); Ignition cartridge – double-base powder (nitrocellulose and nitroglycerin); Fuze M52– Mercury fulminate, lead azide, and tetryl.	TM 43-0001-28
	M44/ Practice	M44 Practice: Steel (chromium, copper, iron, nickel); Spotting charge – Black powder (sulfur, potassium nitrate, charcoal).	TM 9-1904
	M57/ WP Smoke	M57 WP: White phosphorus; Steel (chromium, copper, iron, nickel).	TM 9-1904

Notes:
HE – High Explosive
mm - millimeter
TNT - trinitrotoluene

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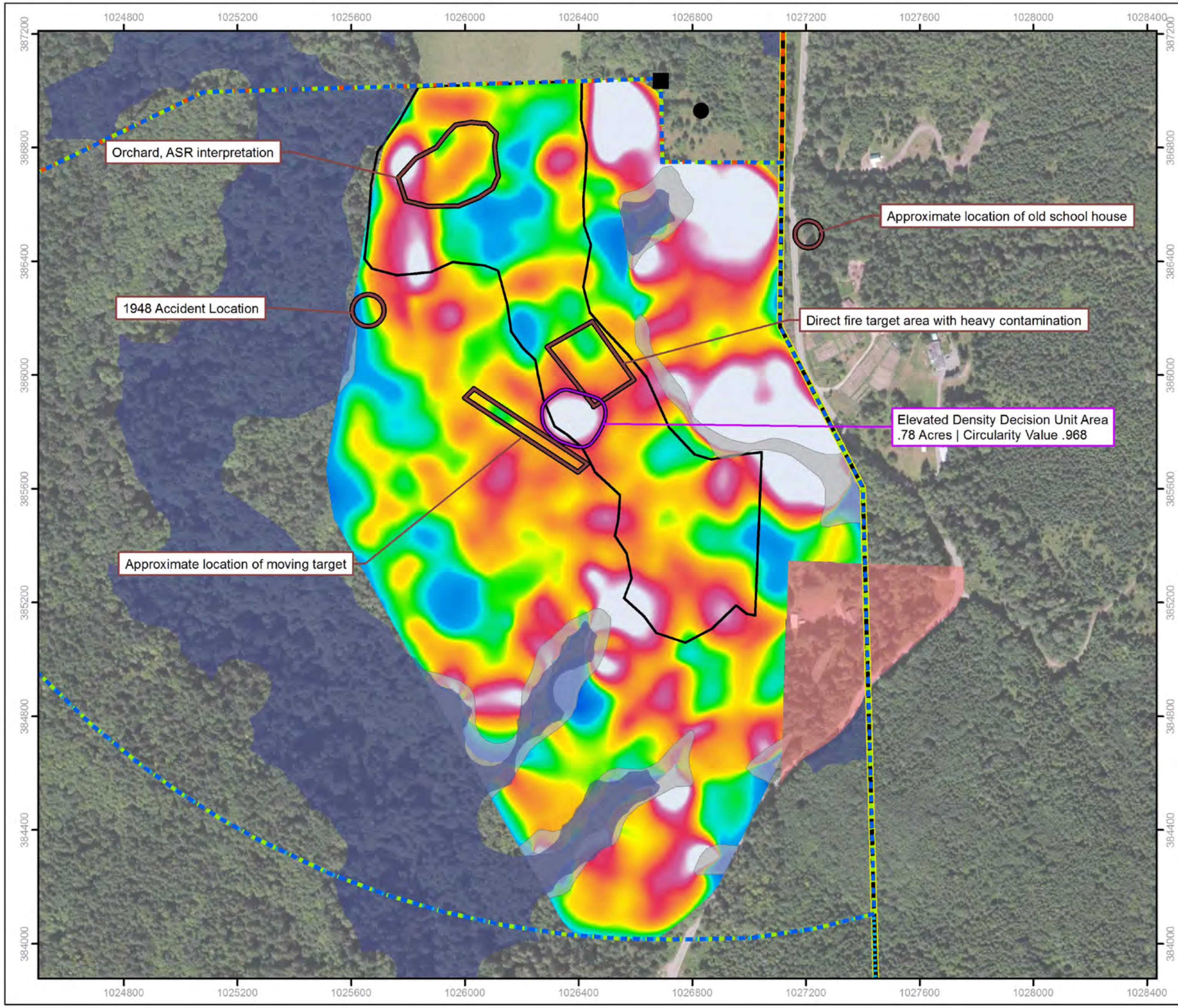

Figure 5-6
EM61 Anomaly Density Technical Approach Area 2 Port Angeles Combat Range, WA

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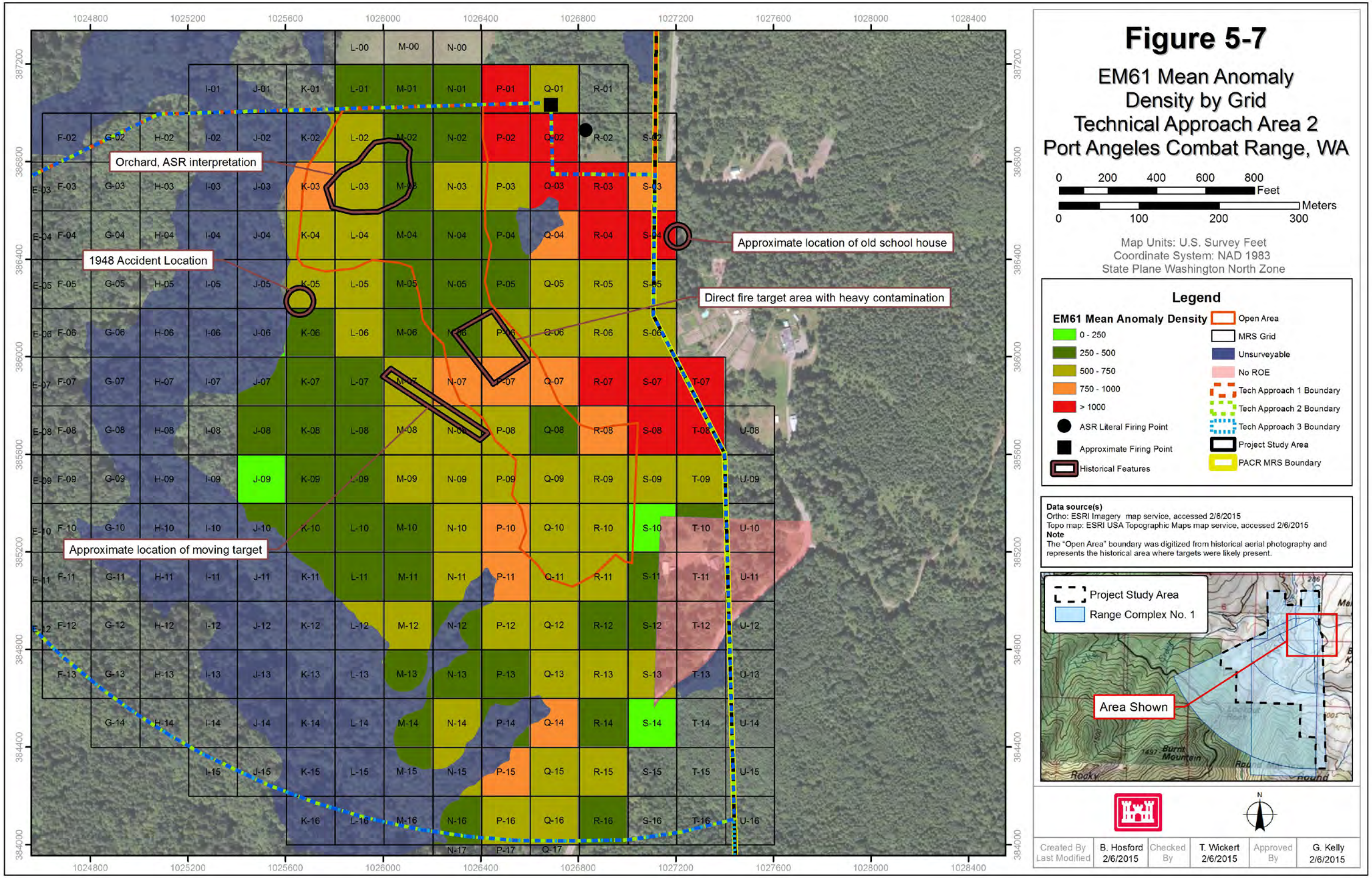
Figure 5-7
EM61 Mean Anomaly Density by Grid
Technical Approach Area 2
Port Angeles Combat Range, WA
0 200 400 600 800 Feet
0 100 200 300 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
EM61 Mean Anomaly Density
0 - 250
250 - 500
500 - 750
750 - 1000
> 1000
ASR Literal Firing Point
Approximate Firing Point
Historical Features
Open Area
MRS Grid
Unsurveyable
No ROE
Tech Approach 1 Boundary
Tech Approach 2 Boundary
Tech Approach 3 Boundary
Project Study Area
PACR MRS Boundary
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Note
The "Open Area" boundary was digitized from historical aerial photography and represents the historical area where targets were likely present.
Project Study Area
Range Complex No. 1
Area Shown
Orchard, ASR interpretation
1948 Accident Location
Approximate location of old school house
Direct fire target area with heavy contamination
Approximate location of moving target
Created By Last Modified
B. Hosford 2/6/2015
Checked By
T. Wickert 2/6/2015
Approved By
G. Kelly 2/6/2015

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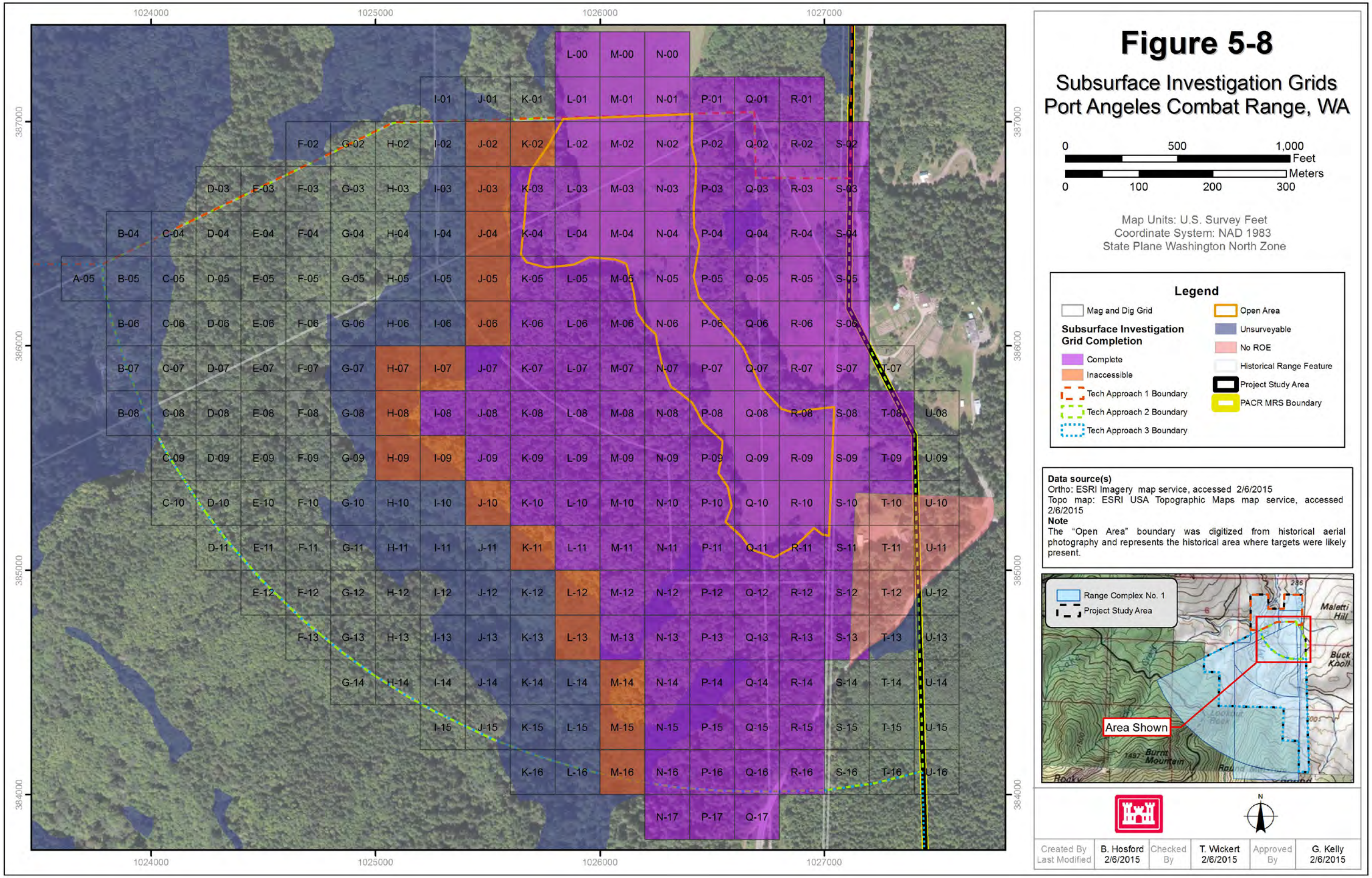

Figure 5-8
Subsurface Investigation Grids
Port Angeles Combat Range, WA

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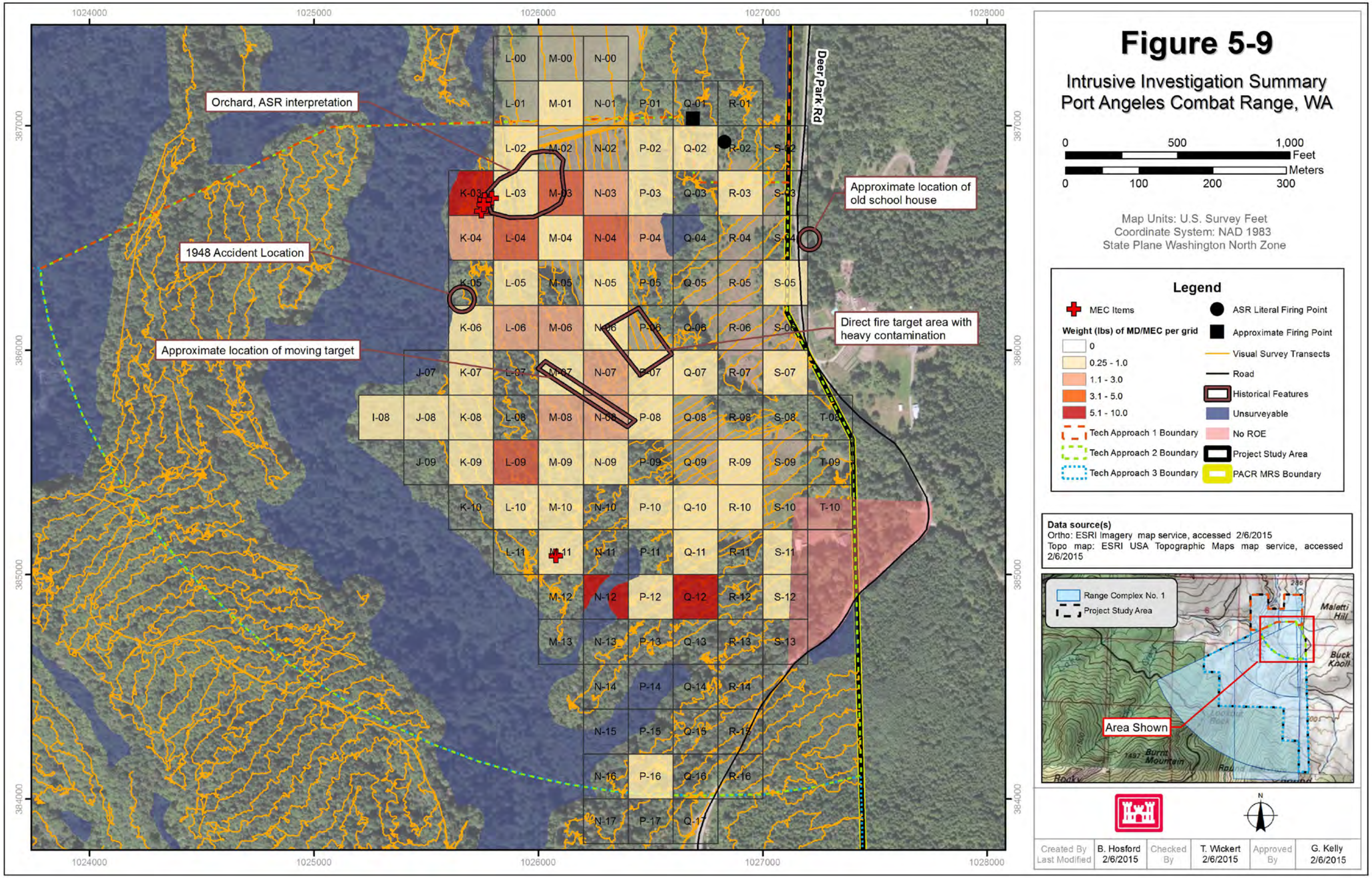
Figure 5-9
Intrusive Investigation Summary
Port Angeles Combat Range, WA
Orchard, ASR interpretation
1948 Accident Location
Approximate location of moving target
Approximate location of old school house
Direct fire target area with heavy contamination
Deer Park Rd
0 500 1,000 Feet
0 100 200 300 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
MEC Items
ASR Literal Firing Point
Approximate Firing Point
Weight (lbs) of MD/MEC per grid
0
0.25 - 1.0
1.1 - 3.0
3.1 - 5.0
5.1 - 10.0
Visual Survey Transects
Road
Historical Features
Unsurveyable
No ROE
Tech Approach 1 Boundary
Tech Approach 2 Boundary
Tech Approach 3 Boundary
Project Study Area
PACR MRS Boundary
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Range Complex No. 1
Project Study Area
Area Shown
Created By Last Modified B. Hosford 2/6/2015
Checked By T. Wickert 2/6/2015
Approved By G. Kelly 2/6/2015

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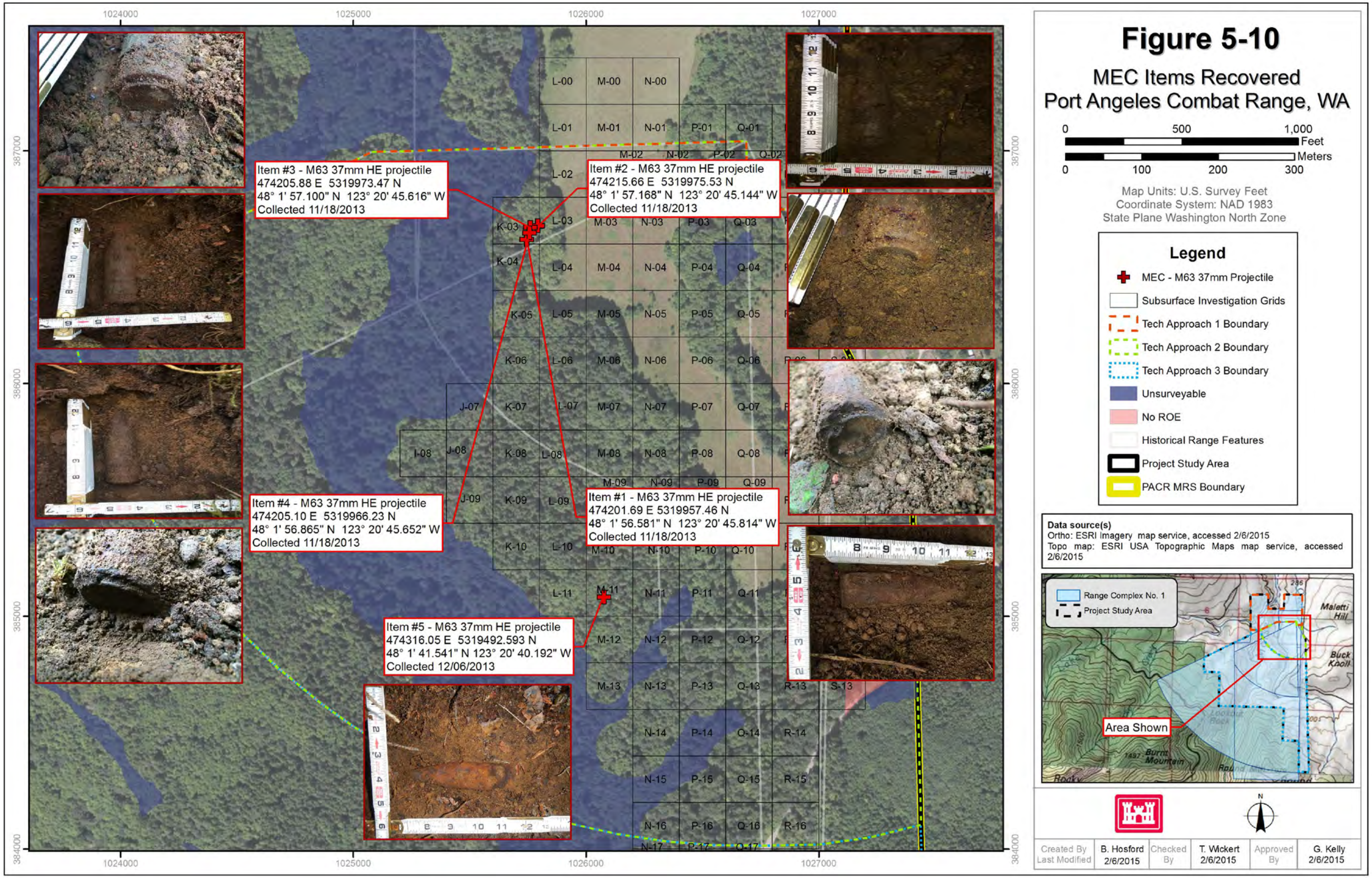
Figure 5-10
MEC Items Recovered
Port Angeles Combat Range, WA
0 500 1,000 Feet
0 100 200 300 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
MEC - M63 37mm Projectile
Subsurface Investigation Grids
Tech Approach 1 Boundary
Tech Approach 2 Boundary
Tech Approach 3 Boundary
Unsurveyable
No ROE
Historical Range Features
Project Study Area
PACR MRS Boundary
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Range Complex No. 1
Project Study Area
Area Shown
Item #3 - M63 37mm HE projectile
474205.88 E 5319973.47 N
48° 1' 57.100" N 123° 20' 45.616" W
Collected 11/18/2013
Item #2 - M63 37mm HE projectile
474215.66 E 5319975.53 N
48° 1' 57.168" N 123° 20' 45.144" W
Collected 11/18/2013
Item #4 - M63 37mm HE projectile
474205.10 E 5319966.23 N
48° 1' 56.865" N 123° 20' 45.652" W
Collected 11/18/2013
Item #1 - M63 37mm HE projectile
474201.69 E 5319957.46 N
48° 1' 56.581" N 123° 20' 45.814" W
Collected 11/18/2013
Item #5 - M63 37mm HE projectile
474316.05 E 5319492.593 N
48° 1' 41.541" N 123° 20' 40.192" W
Collected 12/06/2013
1024000
1025000
1026000
1027000
387000
386000
385000
384000
Created By Last Modified B. Hosford 2/6/2015
Checked By T. Wickert 2/6/2015
Approved By G. Kelly 2/6/2015

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The depths of MD excavated from the subsurface investigation grids varied from 0.5-foot to 1.5-feet. The presence of more deeply buried items in some areas most likely reflects both the variation in soil types and depths, the types of training and firing activities conducted, and types of munitions used.

The combined amounts and numbers of MEC/MD items found in these areas during the AVS and subsurface investigation meet the DQO for identifying surface and subsurface MEC at the PACR. These results, in combination with the degree of corroboration with the historical documentation about the types of activities conducted in these areas are considered sufficient to define the nature and extent of MEC and MD.

5.1.1.4 MD HANDLING, DEMOLITION OPERATIONS, AND MDAS DISPOSAL

During subsurface investigations all MPPEH was inspected in accordance with EM 385-1-97 (USACE, 2008) and EM 1110-1-4009 (USACE, 2007). The MPPEH inspection process is shown in **Figure 4-6** and consisted of the following:

- A UXO Technician II performed a 100% inspection as the item was recovered.
- A UXO Technician III performed a 100% re-inspection.
- The UXOSO/UXOQCS conducted daily audits of the inspection process.
- The UXOSO/UXOQCS insured MPPEH processing was performed safely.
- The SUXOS and UXOSO/UXOQCS performed a 100% inspection at the end of each day to insure that MD was free of explosive hazards. The resulting MDAS was then secured in a locked container.

During subsurface investigations, MPPEH was inspected by the SUXOS or UXOSO/UXOQCS to determine if the item was MEC. If the item was determined to be MD, and not MEC, the debris was handled as MDAS. If the items were determined to be non-munitions related debris the items were left in place.

Upon verification of MEC by the SUXOS or the UXOSO/UXOQCS during subsurface investigations, the SUXOS contacted the Project Manager and the Clallam County Sheriff and Fire District # 2. The Project Manager contacted the USACE and relevant stakeholders.

For the demolition operation, explosives were drawn from the on-site Type II portable magazines located 380 feet south of Deer Park road. Demolition explosives were transported by two UXO Technician IIs on foot to the demolition site in grid Q-09. One of the UXO Tech IIs held a Washington State Blasters Permit. There were three demolition operations required during the field investigation. All MEC items were moved and destroyed in grid Q-09 located in the southern part of the open meadow within Technical Approach Area 2. Demolition operations were conducted on the following dates:

- November 18, 2013 - Four M63 37mm HE projectiles, found during subsurface investigations
- December 6, 2013 - One M63 37mm HE projectile, found during subsurface investigations
- December 12, 2012 - Two pieces of MD (one practice 81mm mortar and one practice 75mm projectile) found during subsurface investigations required demilitarization (demil) to expose internal filler. All remaining project explosives were also destroyed.

MD handling and inspection was required following the demolition operations and at the end of each day during the subsurface investigations. The MD was recovered after the demolition operations, re-inspected and the resulting MDAS was placed in a secure container.

The SUXOS and UXOSO/UXOQCS performed a final 100% inspection of the container at the end of the project, completed and signed DD form 1348-1, locked and sealed the container, and arranged for shipping for final disposition. The DD Form 1348-1 was completed to record the items and to certify them as MDAS and establish a chain of custody. The shipment was delivered to Timberline Environmental Services, an authorized demil contractor via FedEx. The contractor then shredded or smelted the MDAS (50 lbs) and returned official disposition paperwork. These procedures are in accordance with EM 385-1-97 (USACE, 2008). The documentation related to the MD handling and demilitarization is provided in **Appendix I**.

5.1.2 MEC Revised Conceptual Site Model

MEC exposure pathways were evaluated based on the findings from the RI field investigations and updated from the RI Work Plan (HDR, 2013). **Section 8.5.1** summarizes the MRSs, which resulted in the creation of additional CSMs for access and exposure to MEC and MC for all receptors. Range Complex No. 1 and Range Complex No. 1 (a) collectively represent an area of 1,392.2 acres. Range Complex No 1 (b) includes the area within ONP, which is an additional 1,238.5 acres. Additional information was needed to characterize the MRS for nature and extent of MEC and MD, and nature and extent of MC contamination, if any.

5.1.2.1 MEC HUMAN RECEPTORS

Human receptors included in the baseline Human Health Risk Assessment (HHRA) (**Section 7.1**) were as follows:

- Current and Future Recreational User (adult and child)
- Current and Future Outdoor Worker (adult only)
- Current and Future Trespasser (adult and child)
- Current and Future Resident (adult and child)

5.1.2.2 MEC ECOLOGICAL RECEPTORS

Ecological receptors are not assessed for explosive hazards due to MEC; however, consideration must be given to T&E species since loss of an individual animal or plant is considered a “taking” under the U.S. Endangered Species Act of 1973, Prohibited Acts 16 USC § 1538(a) (USC, 2002).

5.1.2.3 MEC TRANSPORT PROCESS

In general, the potential for transport of MEC from one location to another is based on the amount of precipitation, stabilization in soil, the steepness of the slope, and weight of the item. In areas that have steep, open slopes, MEC could be transported by erosion, heavy precipitation events, or possibly by avalanche depending on the slope and cover. There are some smaller surface water features in the Range Complex No. 1 MRS; therefore, MEC transport from initial source locations to surface water or sediment and other areas within the MRS Range Complex No. 1 is possible, although unlikely. Over time, soils, rocks, and organic debris tend to accumulate around stationary items thereby inhibiting movement.

MEC could also be disturbed by intentional or unintentional excavation or digging. Currently, there are no mining operations within the PACR MRSs nor are there any apparent mineral claims (USGS, 2013).

The presence of MD also indicates the potential presence of MEC to at least 18 inches bgs. **Section 5.1.1.3** presents the MD recovered during the RI in detail.

5.1.2.4 MEC MEDIA AND ACCESSIBILITY

The majority of the acreage within the MRSs is undeveloped and privately held; however; limited areas are open to the public for recreational activities. Although recreational use is primarily limited to hunting, other recreational use scenarios were considered. Therefore, recreational users could possibly encounter sub-surface soils during their activities. A few dilapidated fences could effectively limit site access from Deer Park Road. The primary barriers to limit public access to the sites are related to terrain features such as steep cliffs, dense vegetation, wetlands, fallen timber, and lack of trails or roads. Permission from property owners to enter private land also limits access in some areas.

Access to MEC can be limited by the steepness of terrain in portions of the MRSs. Human and mobile ecological receptors could encounter MEC in any accessible area. Although the MMRP focuses on the explosive hazard of MEC to humans, it is noted that any livestock in the MRSs have commercial value to owners as do the abundant wildlife using or inhabiting the area. Some T&E species could possibly contact MEC although this is likely an insignificant exposure scenario.

Exposure media for MEC included surface and subsurface soil. No other environmental media were assessed during the RI; however, both sediment and surface water were considered during CSM development. Surface and subsurface soil were investigated for the presence of MEC during the subsurface investigation described in **Section 5.1.1.3**. The MEC items discovered during the RI (**Table 5-1**) were found in reasonably accessible areas during the subsurface investigation. All MEC items recovered were located on City of Port Angeles property (parcels 47419 and 47490). The MEC found in each of the sampling areas were as follows:

- **Grid K-03**—Four M63 37mm projectiles with residual HE were found in surface soil partially obscured by soil and leaf litter in a predominantly level but heavily forested area, accessible on foot. The general location of items was approximately 50 yards due west of the edge of a meadow (see **Figure 5-10**). Terrain due west of the MEC items (approximately 30 yards) drops off steeply into a ravine.
- **Grid M-11**—One M63 37mm projectile with residual HE was found in surface soil partially obscured by soil and leaf litter in a relatively flat but heavily vegetated area accessible on foot. The general location of this item was approximately 50 yards due west of the edge of a meadow (see **Figure 5-9**), and about 430 yards west of a private residence. Terrain due west of the MEC item (approximately 70 yards) drops off steeply into a ravine.

While MEC was not identified in areas outside of grids K-03 and M-11, MD was recovered throughout the Range Complex No. 1 MRS; therefore, MRS Range Complex No. 1 may potentially contain MEC.

The MEC CSMs for the MRSs are shown in **Figure 5-11** through **Figure 5-13**.

Figure 5-11 Updated Conceptual Site Model for Access to MEC at the Port Angeles MRS Range Complex No. 1 MRS

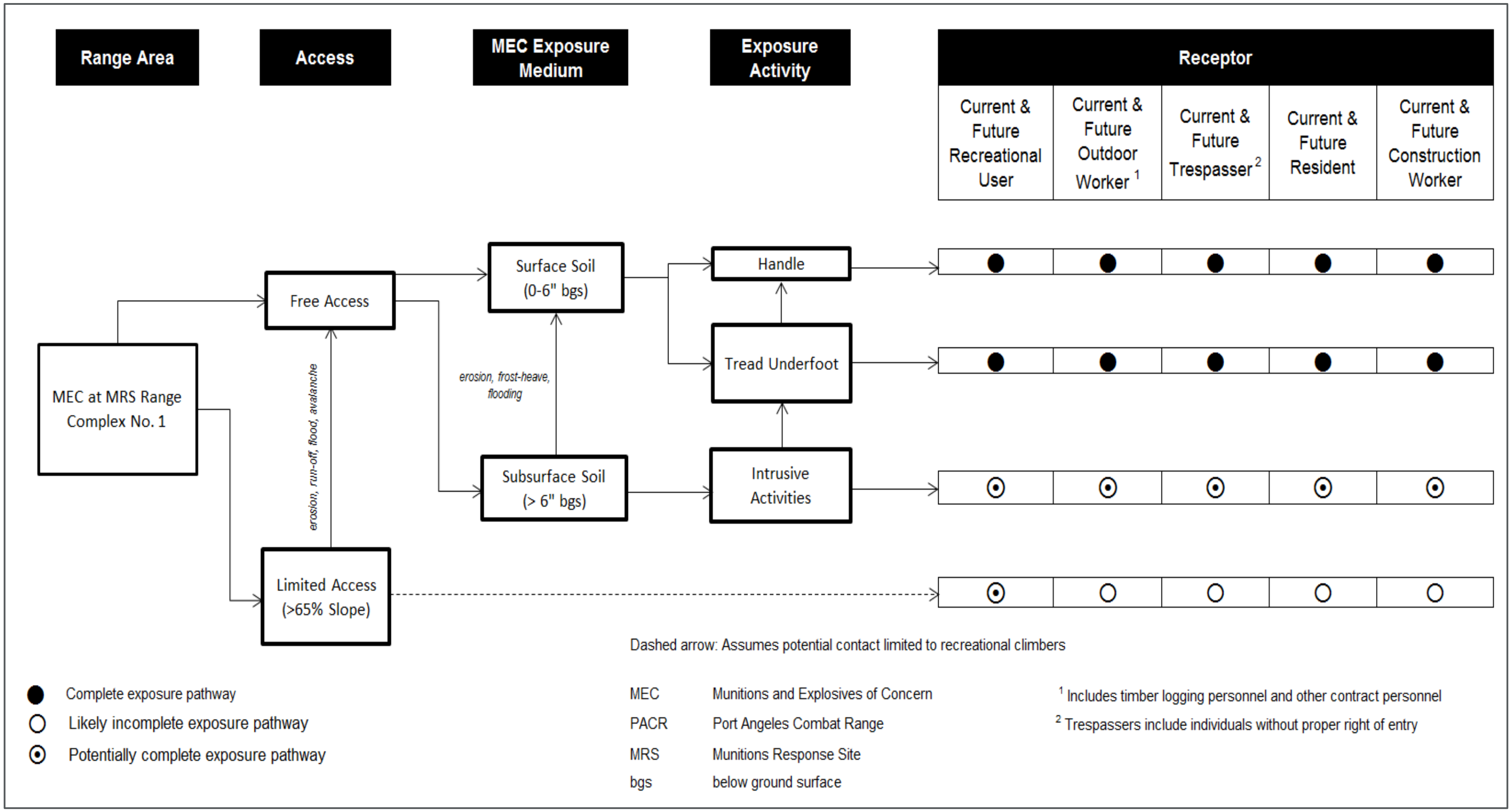
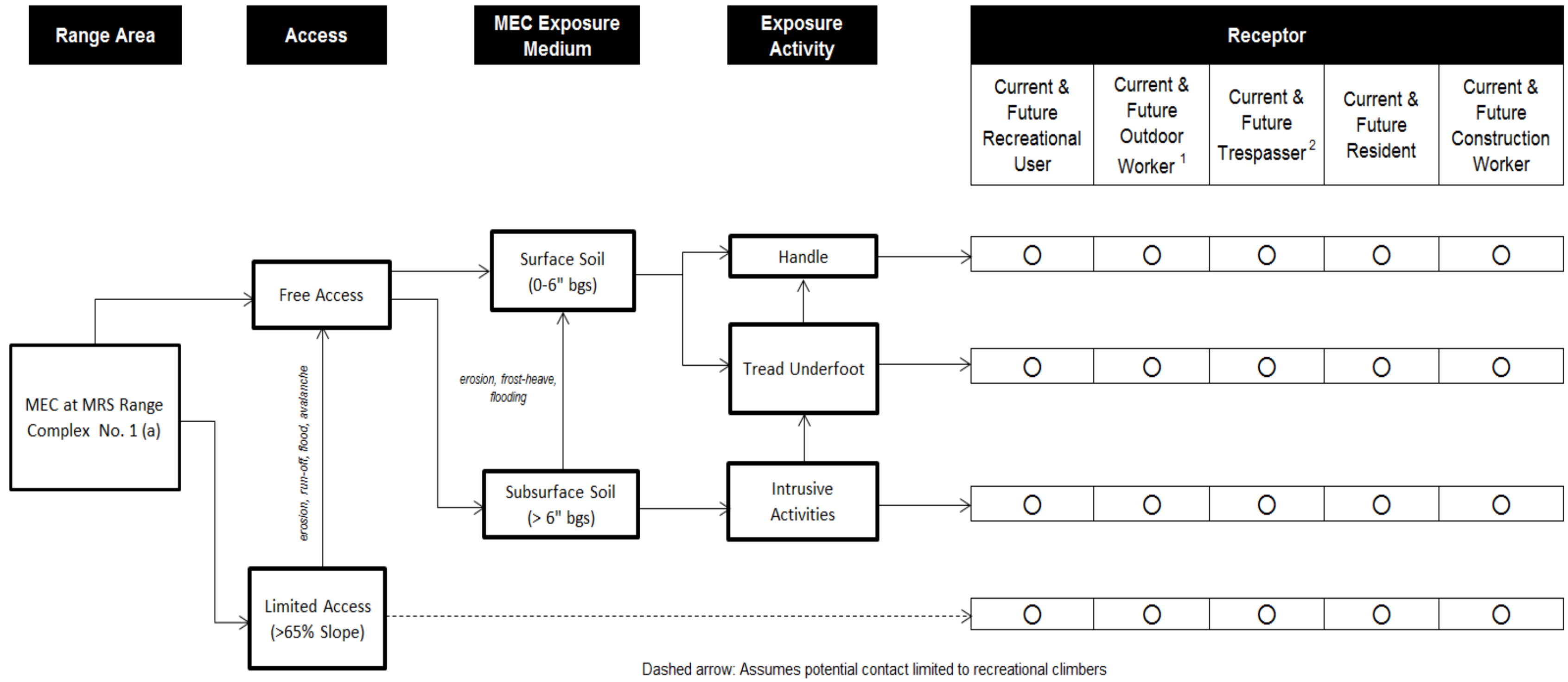


Figure 5-12 Updated Conceptual Site Model for Access to MEC at the Port Angeles MRS Range Complex No. 1 (a)



Dashed arrow: Assumes potential contact limited to recreational climbers

○ Likely incomplete exposure pathway

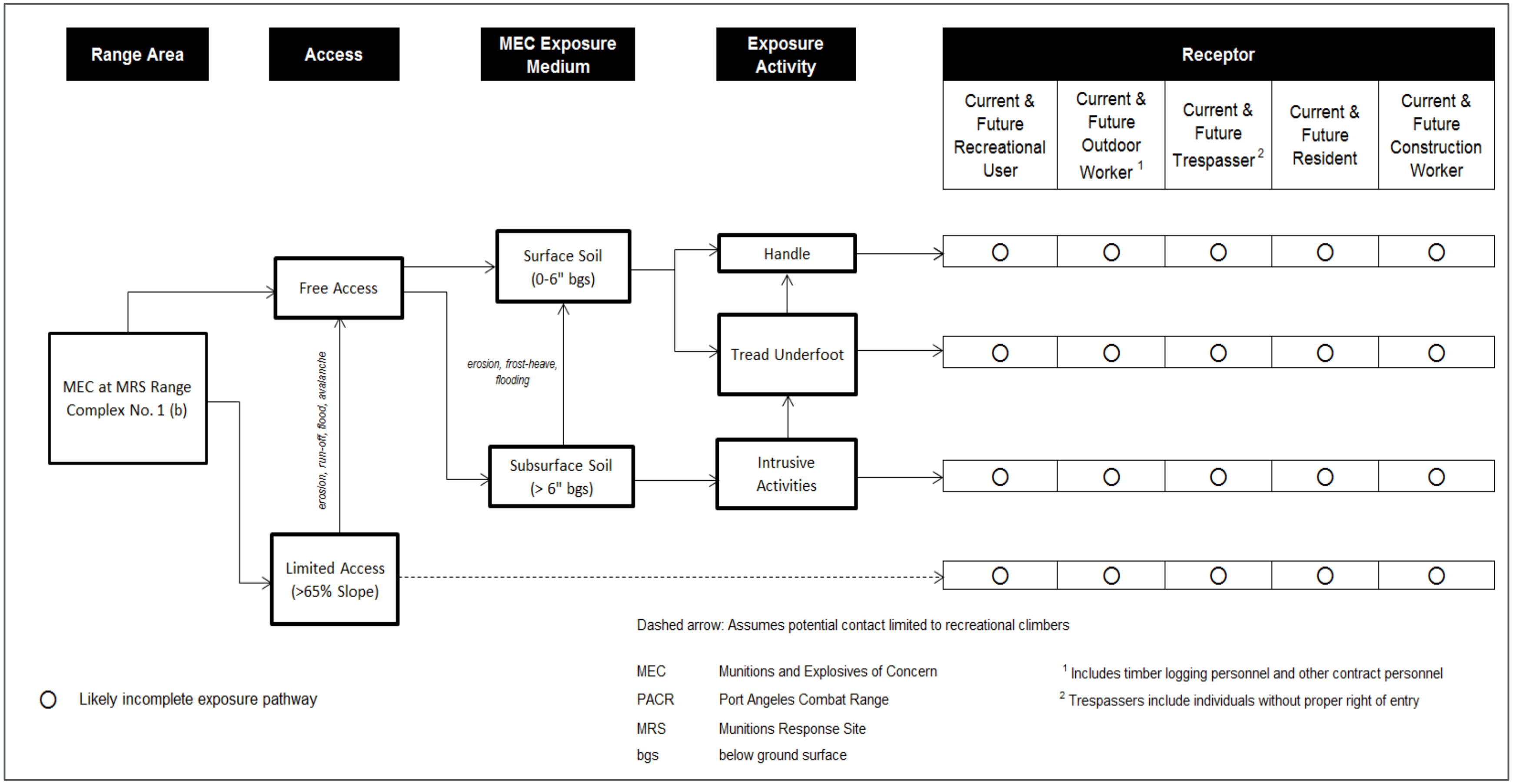
No MEC found at this MRS

MEC	Munitions and Explosives of Concern
PACR	Port Angeles Combat Range
MRS	Munitions Response Site
bgs	below ground surface

[1] Includes timber logging personnel and other contract personnel

[2] Trespassers include individuals without proper right of entry

Figure 5-13 Updated Conceptual Site Model for Access to MEC at the Port Angeles MRS Range Complex No. 1 (b)



5.1.2.5 MEC EXPOSURE CONCLUSIONS

There is the potential for human and ecological receptors to access MEC at the Range Complex No. 1 MRS in surface and subsurface soil. Five MEC items were found during the RI field activities; consequently, all soil exposure pathways for access and exposure to MEC in these MRSs are complete for all receptors. Based on the recovery of semi-buried MEC items (i.e., the M63 37mm HE projectiles at grids K-03 and M-11), surface soil exposure pathways to MEC remain complete. All recovered MEC items were located in shallow surface soil (0-6 inches bgs). MD were present in many areas which suggests that other MEC may be present but not visible. No CWM or evidence of CWM was observed within the MRSs. Range Complex No. 1 (a) and Range Complex No. 1 (b) MRSs are no longer being considered as potentially impacted by MEC.

Munitions debris were recovered to a depth of 18 inches bgs (**Section 5.1.1.3**) which indicates the potential for subsurface MEC as well.

Domestic animals and wildlife are not included as separate receptor categories on the MEC CSMs since they are not assessed for explosive hazards under FUDS.

The following conclusions were reached from the 2013 RI investigation as discussed below.

5.1.2.5.1 Human Receptors (Surface Soil)

Free Access to MEC on or in the surface soil is complete for the following receptors only at MRS Range Complex No. 1:

- Current and Future Recreational Users (Adult and Child)
    - includes hunters, anglers, hikers, backpackers, off – highway vehicle users, et al.
- Current and Future Outdoor Workers (Adult)
    - includes, but not limited to, forest and watershed management personnel
- Current and Future Trespassers (Adult and Child)
- Current and Future Residents (Adult and Child)
- Current and Future Construction Workers (Adult Only)

5.1.2.5.2 Humans Receptors (Subsurface Soil)

Outdoor workers, construction workers, and residents might dig below six inches bgs in the normal course of their activities. It was assumed that intrusive activities would not extend to greater than six inches bgs for recreational users and trespassers, and that these receptors would not dig deeper than six inches bgs under normal circumstances. Intrusive activities initiated by outdoor and construction workers as well as residents may potentially access MEC below six inches bgs since MD was recovered down to 18 inches bgs.

Free Access to MEC in subsurface soil is complete for the following receptors only at MRS Range Complex No. 1:

- Current and Future Outdoor Workers (Adult Only)
    - Includes but not limited to forest and watershed management personnel
- Current and Future Residents (Adult and Child)
- Current and Future Construction Workers (Adult Only)

Under restricted access due to terrain steepness (>65% slope), access to MEC in surface and subsurface soil is potentially complete for the following receptors:

- Current and Future Recreational Users (climbers)

As discussed above, under FUDS, MEC explosive hazard is typically not evaluated for wildlife receptors. If a T&E species is present, injury or mortality is evaluated for an individual of that species rather than a population.

5.2 Munitions Constituents

No environmental sampling for MC analysis was performed during the RI because the conditions that would have warranted the collection of samples for laboratory analysis, as described in **Section 4.2.1**, were not observed during the field investigation.

In-situ sampling for lead utilizing an XRF analyzer was performed to assist the field investigation team to identify any natural features that may have been used for small arms training (e.g., a natural berm feature utilized as a small arms back stop).

5.2.1 MC Investigation Results

5.2.1.1 MUNITIONS CONSTITUENTS – XRF SCREENING RESULTS – LEAD IN SOILS

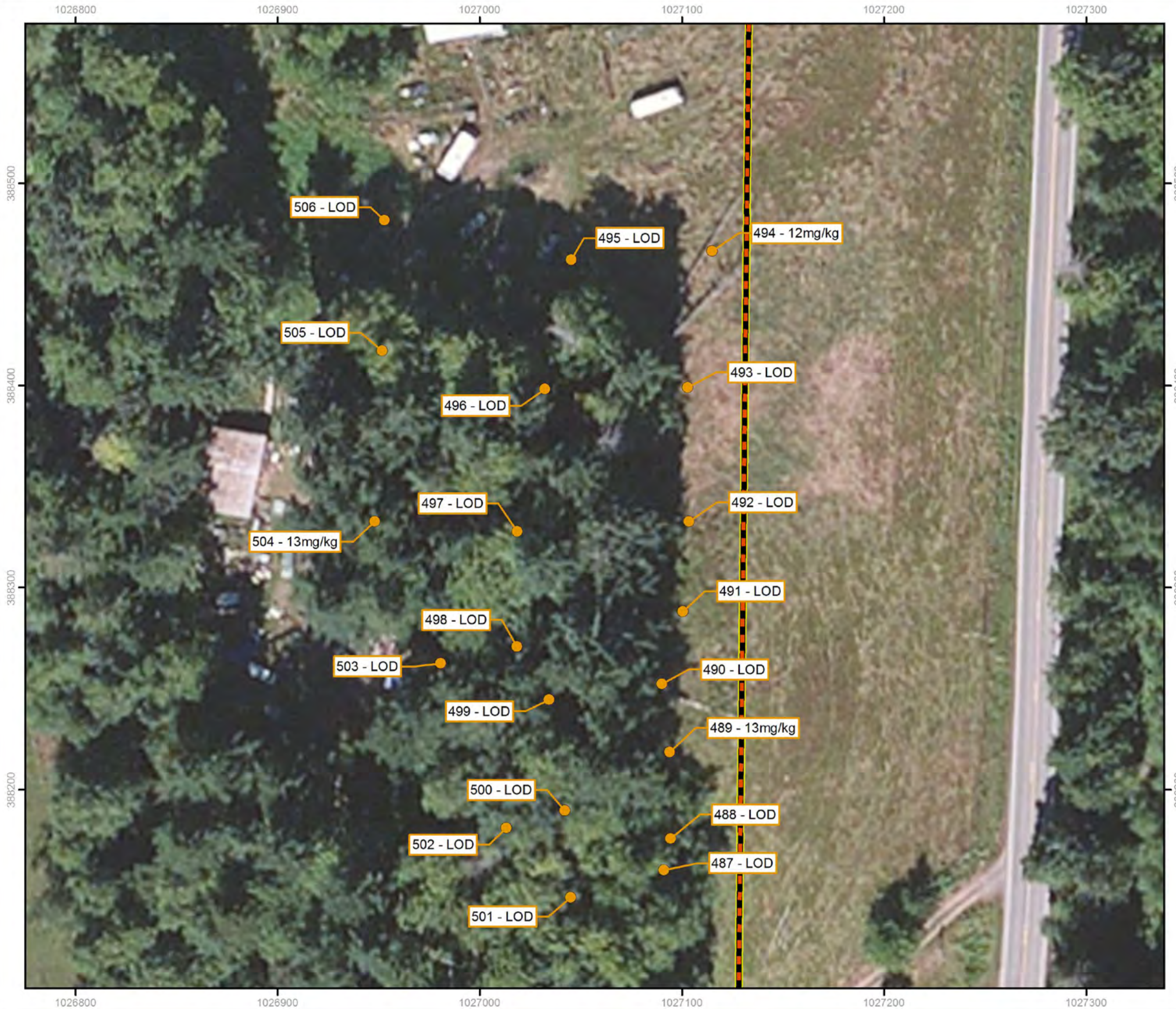
In-situ XRF screening was conducted to analyze for lead in soils where natural features (i.e., natural berm feature) or small arms debris was identified. In-situ XRF screening was utilized to assist the field investigation team to determine sampling locations for laboratory analysis. A conservative in-situ XRF field screening level of 125 mg/kg (compared to the State of Washington soil cleanup level of 250 mg/kg) was utilized to evaluate lead concentrations in soils.

In-situ XRF screening for lead in soil was conducted in two locations where natural features (i.e., natural berm features) where found, and in one location where small arms debris was found. Sixty-eight (68) in-situ XRF screening locations were sampled in two natural features (**Figure 5-14** through **Figure 5-16**). Forty-five (45) in-situ XRF screening locations were also sampled where small arms debris was found (**Figure 5-17**). A total of one-hundred and thirteen (113) in-situ XRF screening samples were collected from the three locations. All in-situ XRF sample results for lead were below the conservative field screening level of 125 mg/kg (**Appendix J**). Thus, no soil samples were collected for laboratory analysis.

The small arms debris included unfired .50 caliber projectiles and links. Due to the presence of the .50 caliber links and the lack of rifling striations it is believed the small arms were likely unfired and deposited in the area, as there are no other indications of an impact area.

Figure 5-14

XRF Screening Locations
Lead in Soil
Port Angeles Combat Range, WA



Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone

Legend

- XRF Screening Location *with sample number and reading*
- Tech Approach 1 Boundary
- Tech Approach 2 Boundary
- Tech Approach 3 Boundary
- Project Study Area
- PACR MRS Boundary

Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Note
LOD= Less than the Limit of Detection. The limit of detection for this project is approximately 10 mg/kg.

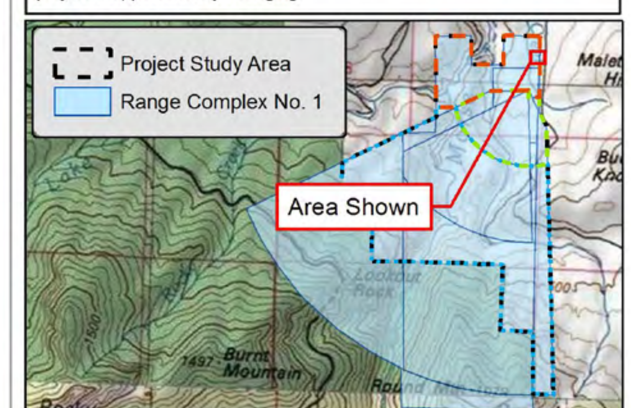


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Figure 5-15

XRF Screening Locations
Lead in Soil
Port Angeles Combat Range, WA

0 50 100 150 Feet

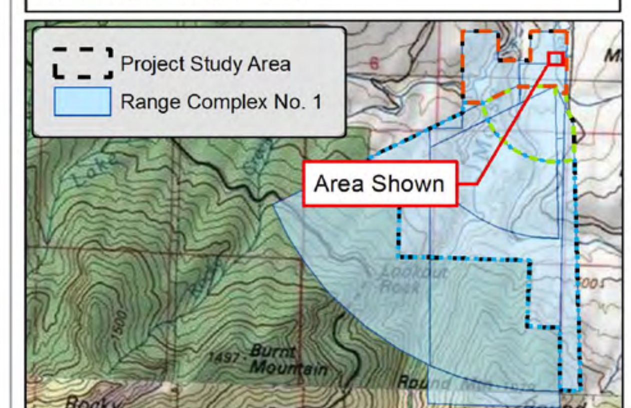
0 10 20 30 40 Meters

Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone

Legend

- XRF Screening Location *with sample number and reading*
- Tech Approach 1 Boundary
- Tech Approach 2 Boundary
- Tech Approach 3 Boundary

Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Note
LOD= Less than the Limit of Detection. The limit of detection for this project is approximately 10 mg/kg.



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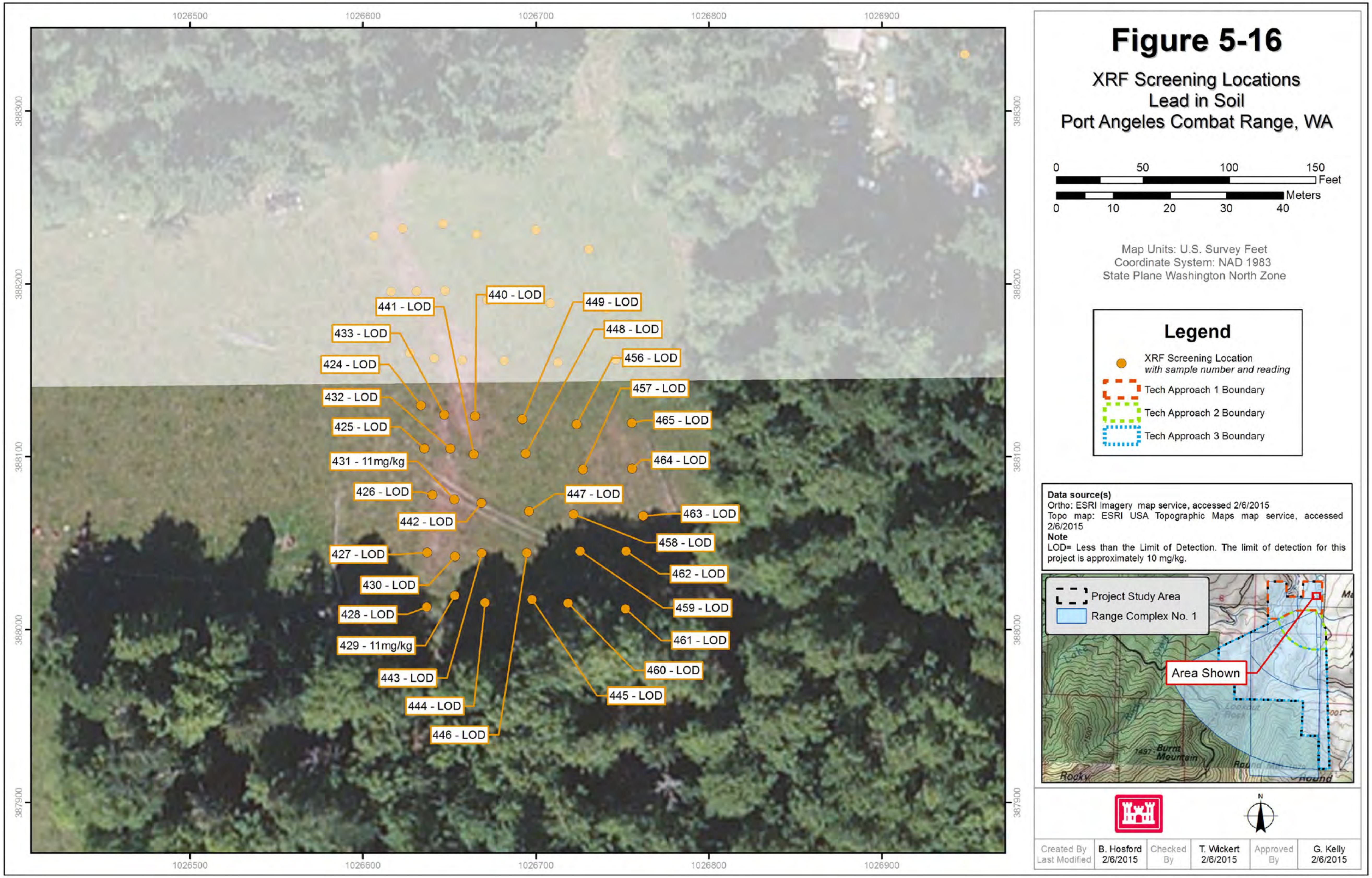

Figure 5-16
XRF Screening Locations
Lead in Soil
Port Angeles Combat Range, WA

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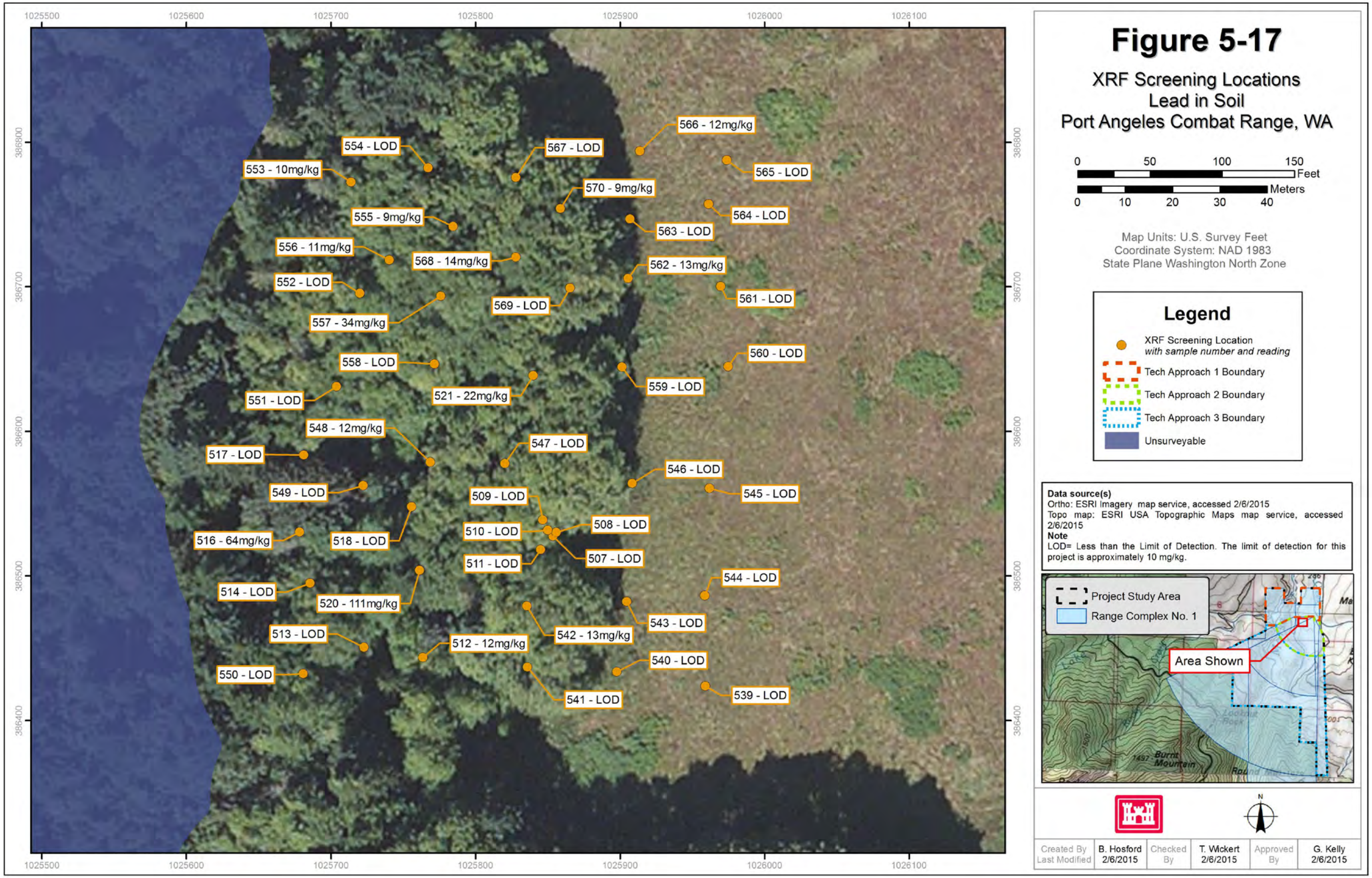

Figure 5-17
XRF Screening Locations
Lead in Soil
Port Angeles Combat Range, WA

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5.2.1.2 MUNITIONS CONSTITUENTS – ENERGETICS SAMPLING – SOIL

Section 4.2.1 and **Figure 4-7** describe the following proposed conditions under which sampling for energetic material and explosives residue would occur:

- Damaged MEC is found, potentially leaching MC into the environment
- A low-order detonation is found, potentially leaching MC into the environment
- MD with visible MC residue is found, potentially leaching MC into the environment

All recovered MEC items were intact and in good condition. MC sampling for energetics and explosives residue was not conducted because a release would not have occurred. All recovered MD items functioned as designed (complete detonation). MC sampling for energetics and explosives residue was not conducted because all explosives associated with the munitions would be consumed during detonation.

5.2.1.3 MUNITIONS CONSTITUENTS – SURFACE WATER, SEDIMENT, AND GROUNDWATER

The decision logic to collect sediment and surface water samples was the same as that for soil sampling and was based on the presence of compromised MEC or observed small arms debris. No MEC, MD, or small arms debris was found in areas of standing or flowing water. Therefore, no surface water or sediment samples were collected during the RI.

During the RI field investigation, field teams noted evidence of seeps, springs, and surface to groundwater communication (i.e., hydrogeological connections). No MEC, MD, or small arms debris were found in saturated areas. Therefore, no groundwater sampling was conducted during the RI.

5.2.1.4 ANALYSIS AND INTERPRETATION OF VISUAL SURVEY AND SUBSURFACE INVESTIGATION RESULTS

The results of the AVS, geophysical surveys, subsurface investigation, and the XRF analysis conducted during the RI field effort comprise a comprehensive data set that can be compared with historical information about the ranges and munitions use to provide a more probable representation of how the MRS was configured. This information was used to assess the potential for remaining explosive hazards, as described in the following discussion.

5.2.1.4.1 Impact and Target Areas

Based on the results of the AVS and the subsurface investigation, target and impact areas were confirmed to exist within the MRS. These areas contained MEC, MD, or small arms debris as well as evidence of old target features such as vehicle and other metallic debris. The areas that were investigated as part of the subsurface investigation located all of the impact and target areas within the MRS. Because there were two fatalities when timber was harvested (i.e. MEC embedded in trees) and trees still exist within the MRS there are likely additional MEC embedded within the tree trunks. The presence of MEC embedded in the tree trunks would be limited to those trees that were present when the range was operational.

There were three general locations that contained higher densities of MD relative to the rest of the MRS. **Figure 5-9** depicts the weights of MD, MEC, and small arms debris removed from each grid. The summarized weight of the items is only representative of approximately 10% of each subsurface investigation grid; however, the relative density of MD in each grid was still assessed.

The first area is located in the north central portion of Technical Approach Area 2 in the proximity of grid L-04. This impact and target area contained evidence of artillery (37mm projectiles and HE frag), mortars (81mm) and small arms (.50 caliber).

The second area is located in the central portion of Technical Approach Area 2 in the proximity of grid N-07. Within this impact and target area similar evidence was found as described above including artillery (37mm projectiles and HE frag), mortars (81mm) and small arms (.50 caliber).

The third area is located in the southern portion of Technical Approach Area 2 in the proximity of grid P-12. Evidence of munitions in this area was limited to artillery (75mm projectiles and HE frag). The distance from the firing point to the furthest location where MD was recovered is approximately 1,000 yards. The ASR noted that the distances of 500 yards to 1,000 yards from the firing point likely contain the “over fired” munitions. Therefore the third area may be an impact area with “over fired” munitions.

All of the munitions identified during the RI are effective up to a distance of 1,000 yards; therefore, all types of munitions are estimated to be present within each impact and target area. The depth of subsurface MD varied from 0.5-foot to 1.5 feet bgs.

While distinct impact and target areas containing higher relative densities of MD were observed, the areas adjacent to and between these target features are also estimated to contain MEC and MD.

The small arms debris located in grids K-03 and K-04 included unfired .50 caliber projectiles. Grid L-04 contained unfired .50 caliber projectiles and links. Due to the presence of the .50 caliber links and the lack of rifling striations it is believed the small arms were likely unfired and deposited in the areas, as there are no indications of a separate small arms impact area. If small arms were used at the MRS they were likely fired at the artillery and mortar targets.

5.2.1.4.2 Comparison of RI Findings with Historical Information

The locations of the impact and target areas described above in **Section 5.2.1.4.1** were compared to the locations of the historic features identified in the ASR. The ASR identified the following locations of historic munitions related features either textually or graphically (**Figure 2-8**) including:

- Intended indirect fire impact area
- An orchard which mortars were fired over
- 1948 Accident Location (location where two youths were killed in 1948)
- Direct fire target area with heavy contamination
- A moving target
- An old school house
- Firing point

The historical context of the intended Indirect Fire Impact Area was mortars were fired over the orchard and into the impact area. During the AVS within Technical Approach Area 3 which contained the anticipated location of the area of intended indirect fire impact there were no MD or other evidence of munitions identified. Initially this was a concern because the project team expected to find mortars within this area. Subsequent to the completion of the AVS within this area, mortar debris was identified to the west and south of the historical location of the orchard. The historical context that mortars were fired over the orchard in the ASR was correct; however, the initial locations of the associated impact areas were incorrect. The impact areas associated with the mortars were closer to the firing points than initially anticipated. Based on the results of the RI field investigation the location of the intended Indirect Fire Impact area presented on **Figure 2-8** is no longer considered relevant.

The results of the RI field investigation corroborated the locations of the 1948 Accident Location, the location of the direct fire target area with heavy contamination, and the moving target. These areas were confirmed based on the MD and MEC recovered near these locations. In addition to the anticipated locations of the historical features an additional impact and target area was identified which was not previously discussed in the ASR.

The location of the old school house is relevant to confirm the direction of fire. It is unlikely that munitions would have been fired in the direction of the schoolhouse. The locations of the MD and MEC recovered during the RI confirmed that the direction of fire was from the firing point to the south.

The historical location of the firing point is discussed below in **Section 5.2.1.4.3**, firing point and range analysis.

Historical features that could not be located include:

- A potential small arms range
- A potential maneuver area containing practice land mines

Small arms debris (.50 caliber) were identified within the impact and target areas as described above in **Section 5.2.1.4.1**. In-Situ XRF samples were also analyzed at the natural topography features that could have been utilized as a small arms range berm. During the XRF analysis and the AVS there were no small arms debris observed at the natural topographic features. All of the XRF results were either below the limit of detection (approximately 10 mg/kg) or significantly below regulatory screening levels. Based on these results there was likely never a separate small arms range and the mortar and artillery targets described above in **Section 5.2.1.4.1** were utilized for small arms training.

The AVSs were performed throughout the accessible areas of the possible maneuver area identified in the ASR (Technical Approach Area 1) that could potentially contain landmines. There was no evidence of landmines identified including the presence of landmines, packaging material (e.g., crates) or dunnage. In addition, there was no other evidence that indicated the area was used for maneuvers or an infiltration course such as communication wire, c-ration cans, fox-holes, barbed wire obstacles, etc. If landmines did exist at the MRS it is possible that they could have been removed during the previous clearance efforts since they are readily visible. The information within the ASR indicated that the use of land mines was not confirmed. Based on the lack of evidence indicating the use of land mines during the field investigation and that the ASR could not confirm that land mines were actually used, it is unlikely land mines are present within the MRS.

5.2.1.4.3 Firing Point and Range Analysis

The configuration of the MRS was analyzed based on the results of the field investigation. Distances that munitions can travel and the typical deployment of the munitions were compared to the locations of the MEC and MD recovered during the RI. The following munitions and firing distances were included based on MEC/MD discovered during the RI and previous investigations:

- M43A1 81mm mortar, maximum firing distance of 565 yards (ignition cartridge only) to 4,050 yards (ignition cartridge and eight increment charges)
- M47 75mm projectile, maximum firing distance 9,620 yards
- M63 37 HE mm projectile, maximum firing distance 4,980 yards

It should be noted that the maximum firing distance does not coincide with the maximum effective range. The maximum firing distance is the extent that a munitions item can physically travel. The maximum effective range is typically much less (e.g., a small arms pistol is only effective to 25 yards but the bullet could potentially travel 2,500 yards). The maximum effective range was considered when evaluating the firing points and the configuration of the MRS.

Based on the locations of the impact and/or target areas that were identified it is believed that the ASR firing point was located incorrectly or that they were limited to a secondary firing position (**Figure 5-18**). Based on the ASR interviews and distances to the targets the firing point was likely located in the larger meadow further to the west and north. Direct fire exercises would have also likely been performed in areas with open line-of-sight. Positioning the firing point in the larger meadow meets the typical deployment of weapons used at that time and corroborates the interviews from the ASR. The fragmentation distances of the munitions were compared to the distance between the ASR firing point and the target and impact areas. The distance between the ASR firing point and the target and impact areas are less than the munitions fragmentation distances (i.e., HE frag would impact the ASR firing points). The incorrect location of the ASR firing point is further evidenced by the fact that munitions debris was identified in grids directly adjacent to the ASR firing point (grids Q-02 and R-03). The precise location of the firing point does not directly affect the location of MEC/MD; however, it allows for a more robust analysis and supports the absence of MEC in other areas. A line of sight analysis was performed utilizing the target and firing point locations determined during the RI (**Figure 5-19**). The line of sight conservatively assumed a two degree elevation angle (angle off of the horizon) during the analysis, which equals approximately 50 feet above a target at 500 yards and 70 feet above a target at 700 yards. Areas within the line of sight model and outside of the impact and target areas were investigated during the AVS. No MEC or MD was identified within these areas which corroborates it is not probable for MEC or MD to be present outside of the impact and target areas.

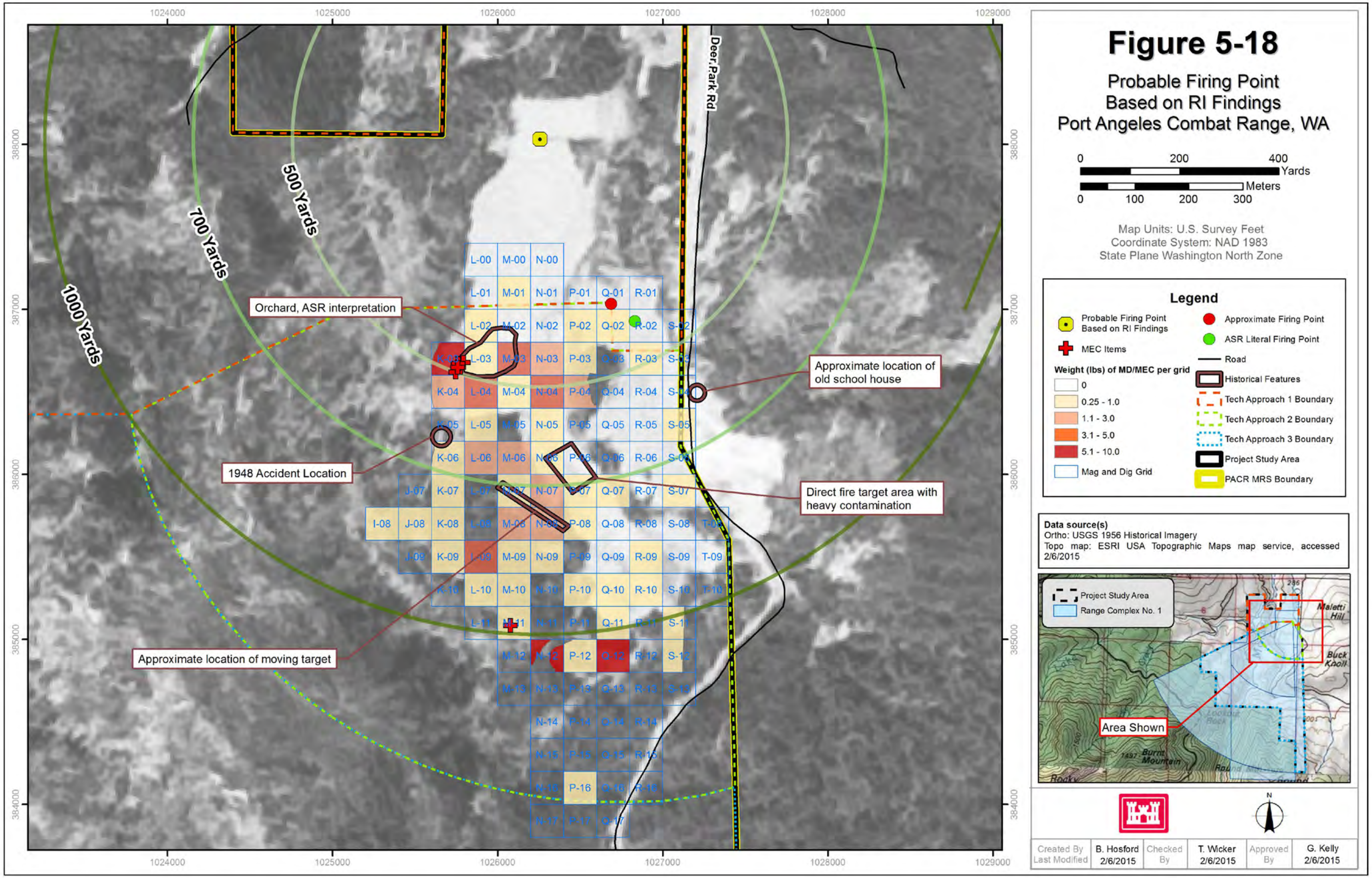
Figure 5-18
Probable Firing Point
Based on RI Findings
Port Angeles Combat Range, WA
0 200 400 Yards
0 100 200 300 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
Probable Firing Point Based on RI Findings
MEC Items
Approximate Firing Point
ASR Literal Firing Point
Road
Weight (lbs) of MD/MEC per grid
0
0.25 - 1.0
1.1 - 3.0
3.1 - 5.0
5.1 - 10.0
Mag and Dig Grid
Historical Features
Tech Approach 1 Boundary
Tech Approach 2 Boundary
Tech Approach 3 Boundary
Project Study Area
PACR MRS Boundary
Data source(s)
Ortho: USGS 1956 Historical Imagery
Topo map: ESRI USA Topographic Maps map service, accessed 2/6/2015
Project Study Area
Range Complex No. 1
Area Shown
Maletti Hill
Buck Knoll
Burnt Mountain
Created By Last Modified
B. Hosford 2/6/2015
Checked By
T. Wicker 2/6/2015
Approved By
G. Kelly 2/6/2015
Orchard, ASR interpretation
Approximate location of old school house
1948 Accident Location
Direct fire target area with heavy contamination
Approximate location of moving target
Deer Park Rd
500 Yards
700 Yards
1000 Yards

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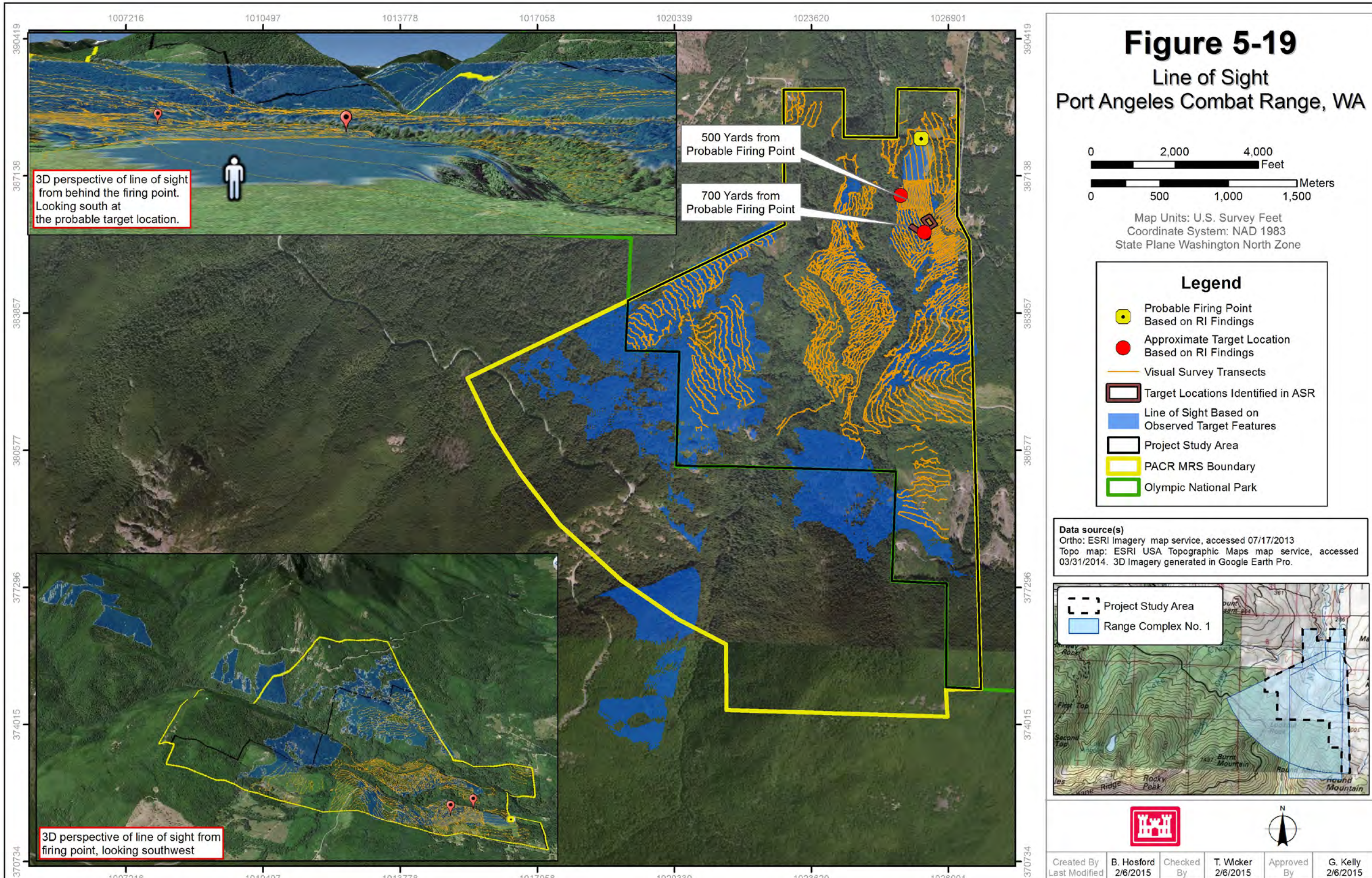
Figure 5-19
Line of Sight
Port Angeles Combat Range, WA
0 2,000 4,000 Feet
0 500 1,000 1,500 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
Probable Firing Point Based on RI Findings
Approximate Target Location Based on RI Findings
Visual Survey Transects
Target Locations Identified in ASR
Line of Sight Based on Observed Target Features
Project Study Area
PACR MRS Boundary
Olympic National Park
Data source(s)
Ortho: ESRI Imagery map service, accessed 07/17/2013
Topo map: ESRI USA Topographic Maps map service, accessed 03/31/2014. 3D Imagery generated in Google Earth Pro.
Project Study Area
Range Complex No. 1
500 Yards from Probable Firing Point
700 Yards from Probable Firing Point
3D perspective of line of sight from behind the firing point. Looking south at the probable target location.
3D perspective of line of sight from firing point, looking southwest
1007216
1010497
1013778
1017058
1020339
1023620
1026901
390419
387138
383857
380577
377296
374015
370734
N
Created By Last Modified
B. Hosford 2/6/2015
Checked By
T. Wicker 2/6/2015
Approved By
G. Kelly 2/6/2015

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5.2.1.5 VISUAL SAMPLING PLAN ANALYSIS

A VSP analysis was performed to provide a statistical basis for determining the extent of possible MEC/MD contamination and to determine whether additional target or impact areas may have been missed at the MRS. The visual sampling plan reports are provided in **Appendix K**.

The VSP application was developed by Pacific Northwest National Laboratory with support from the Department of Energy (DOE), the USEPA, the DoD, the Department of Homeland Security (DHS), the Centers for Disease Control (CDC), and the United Kingdom (PNNL, 2011). The stated objective of the software development is "to ensure that the right type, quality, and quantity of data are gathered to support confident decisions." For the PACR RI, VSP was used to develop transect spacing to ensure proper survey methodologies were applied to historical site use patterns. For the assessment, two VSP modeling workflows were considered:

1. **Workflow 1** - Probability of traversal utilizes a Monte Carlo simulation to model the probability that transects would intersect a target area of a given size and shape (represented by a circularity value between 0.2 for an ellipse and 1 for a circle).
2. **Workflow 2** - Probability of traversal and detection utilizes the same methodology as the first workflow with the additional ability to model detection rates for geophysical sensors at specified confidence levels.

For activities at the MRS, three scenarios were considered for VSP modeling, in all scenarios unsurveyable areas shown in **Figure 4-2** were masked and not considered in the modeling results:

Scenario 1: In the open meadow where target features were historically located, 35-foot AVS and DGM transects were collected. This allowed for the assessment of probability of traversal and detection (Workflow 2). The underlying purpose of the DGM survey was to determine the appropriate follow on activity and to delineate regions of high density (greater than 250 anomalies per acre) from a nominal background density level that could be expected in the environment. Within Technical Approach Area 2, this occurred with the intent that high-density areas identified in the DGM process would be subject to subsequent intrusive investigations. However, the result of the DGM transects indicated elevated density levels throughout the open meadow and thus necessitated an intrusive subsurface investigation of the entire open meadow. The intrusive subsurface investigation determined nature and extent of the areas impacted by MD/MEC. This eliminates the underlying need to perform an assessment of the probability of a target area being detected by VSP modeling. **Figure 5-8** shows the extent of the subsurface investigation in relation to the open meadow.

One important ancillary outcome of the density analysis is that the presumption of the original decision unit of a 0.7 acre target area was tested against the actual density data from the DGM as centered on grids P-07 and N-07. This elevated area was selected due to its proximity to the area described as "Direct Fire Target Area with Heavy Contamination" in the ASR. The outcome of this test empirically derived the decision unit for a target area at the Range Complex No. 1 MRS is 0.783 acres with a circularity value of 0.968 (circularity = 4pi [area/perimeter^2]). These parameters were used as test values for the following two inputs; this area is shown in **Figure 5-7**.

Scenario 2: The surveyable 75-foot transect spacing areas were tested for probability of traversal (Workflow 1) at the decision unit acreage of 0.783 acres with a circularity value of 0.968. This test unit represents the decision unit polygon discussed in the previous paragraph. A VSP Monte Carlo simulation of the area indicated a 100% probability of traversal of these areas given 10,000 randomly placed sample locations.

Scenario 3: The surveyable 150-foot transect spacing areas were tested for probability of traversal (Workflow 1) at the decision unit acreage of 0.783 acres with a circularity value of 0.968. This test unit represents the decision unit polygon discussed in the previous paragraph. A VSP Monte Carlo simulation of the area indicated a 99% probability of traversal of these areas given 10,000 randomly placed sample locations.

It should be noted that the targets utilized during direct fire exercises are anticipated to be smaller than indirect fire targets because of the method of deployment (i.e., indirect fire targets will inherently be larger). Therefore, utilizing the decision unit of 0.783 acres is a conservative measure and all targets within the MRS have been detected. The results of the three scenarios are presented in **Table 5-3**.

Table 5-3 VSP Results for Scenarios 1-3

Name	Description	VSP Traversal Result
Scenario 1	DGM performed 35-foot Transect Spacing	Not considered due to subsequent intrusive investigation activities
Scenario 2	Assisted Visual Surveys 75-foot Transect Spacing	100% Traversal
Scenario 3	Assisted Visual Surveys 150-foot Transect Spacing	99% Traversal

The VSP application was also utilized to compare anticipated traversal rates from the project planning phase with the actual coverage achieved in the surveyable areas of the site. During the RI Work Plan (HDR, 2013) development process, VSP was utilized to provide transect spacing to match the known historical site use. For planning purposes, idealized straight line surveys were modeled. Due to the heavy vegetation and extreme topography at the MRS, meandering transects were utilized in the field. It should also be noted that VSP was utilized as an input in the planning process that ultimately determined the 0.7-acre decision unit utilized in the RI Work Plan (HDR, 2013) modeling and adjusted to field results for the final VSP analysis. This analysis incorporated VSP models generated for theoretical targets from the very small (0.1-acre), to a comparatively large (1.0-acre) target area. The following results demonstrate that the outcomes from the visual surveys were consistent with project planning activities (**Table 5-4**).

Table 5-4 Comparison of VSP Results of Planning Outputs Compared to Field Data

Transect Spacing	75-foot	75-foot	150-foot	150-foot
Target Area Size and Shape	**Planned/straight**	**Actual/meandering**	**Planned/straight**	**Actual/meandering**
1-acre circle	100%	100%	100%	100%
1-acre/ellipse	100%	100%	98%	99%
0.5-acres/circle	100%	100%	100%	99%
0.5-acre/ellipse	100%	99%	93%	97%
0.25-acre/circle	100%	100%	81 %	89%
0.25-acre/ellipse	98%	97%	87%	92%

5.2.2 MC Revised Conceptual Site Model

The graphical CSMs developed for the RI Work Plan (HDR, 2013) have been revised by incorporating the results from the 2013 RI fieldwork. **Section 8.5.1** summarizes the MRSs, which resulted in the creation of additional CSMs for access and exposure to MEC and MC for all receptors. Range Complex No. 1 and Range Complex No. 1 (a) collectively represent an area of 1392.2 acres. Range Complex No. 1 (b) includes the area within ONP, which is an additional 1238.5 acres. Additional information was needed to characterize the MRS for nature and extent of MEC and MD, and nature and extent of MC contamination, if any. CSMs for human and ecological receptors potential exposure to MC are presented inn the CSMs that follow (**Figure 5-20** through **Figure 5-25**).

5.2.2.1 HUMAN RECEPTORS POTENTIALLY EXPOSED TO MC

The potential remains for human receptors to encounter both MEC and possibly MC in compromised munitions at the MRS Range Complex No. 1. Consequently, all human receptors are potentially exposed to MC in surface soil; other receptors might conduct intrusive activities into the subsurface soil.

Based on the results of the sampling conducted in the SI (i.e. stakeholders agreed that further MC sampling is not warranted) and the lack of MEC requiring MC sampling during the RI the exposure pathways to MC are considered incomplete and thus there are no receptors for the Range Complex No. 1 (a) and Range Complex No. 1 (b) MRSs.

5.2.2.2 ECOLOGICAL RECEPTORS POTENTIALLY EXPOSED TO MC

Ecological receptors potentially evaluated for exposure to MC in the Baseline Ecological Risk Assessment (BERA) (**Section 7.2**) included:

- Terrestrial plants
- Terrestrial soil invertebrates (soil fauna)
- Terrestrial birds
- Terrestrial mammals
- Aquatic receptors (plants, invertebrates, vertebrates, aquatic-dependent mammals and birds)

5.2.2.3 MC EXPOSURE MEDIA AND ACCESSIBILITY

Soil, sediment, surface water, and groundwater sampling data from the SI (Shaw, 2009) reported that the results were associated with naturally occurring background concentrations or were below relevant human health and ecological screening values.

The five MEC items removed from the MRS Range Complex No. 1 appeared intact such that additional environmental sampling for MC was deemed unnecessary. The potential exists for additional surface and subsurface MEC, which can result in potential MC contamination; however, based on the types and densities of the MD observed it is likely insignificant. Consequently, most of the soil exposure pathways are potentially complete in the absence of environmental sampling.

None of the recovered MEC were compromised to the extent that MC was likely released to the environment. Consequently, no environmental media sampling and analysis was conducted.

There have been multiple range clearances on the PACR since WWII; however, due to steep terrain features and lack of ROE of four parcels including the ONP, areas remain which have not been evaluated. MEC and MC are potentially present in those areas as well as locations that were unsurveyable due to dense vegetation. Based on the line of sight analysis and the proximity of the ONP in relation to the identified target and impact areas it is unlikely that MEC are present in the ONP.

The potential remains for human receptors to encounter both MEC and MC at the MRS Range Complex No. 1. For MRS Range Complex No. 1, exposure pathways are potentially complete (**Figure 5-20**). Human receptors are unlikely to be exposed to MC in soils at the Range Complex No. 1 (a), and Range Complex No. 1 (b) (**Figure 5-21** and **Figure 5-22**, respectively). Based on the results of the RI field investigation it is unlikely that MEC and MC are present in Range Complex No. 1 (a) and Range Complex No. 1 (b).

Exposure parameters and toxicity data for reptiles are very limited. Any possible evaluation of risks to mammals and birds would likely be protective of terrestrial reptiles.

5.2.2.4 MC POTENTIAL ROUTES OF MIGRATION

Environmental media concentrations from the SI (Shaw, 2009) were reported as naturally occurring and/or below human health and ecological screening values.

During the RI, no MEC or MD constituting an MC source (for criteria, see **Section 0**), were observed, analyzed, or assessed; therefore, potential routes of migration are likely non-existent or potentially complete though likely insignificant.

5.2.2.5 MC CONTAMINANT PERSISTENCE

The environmental media concentrations from the SI (Shaw, 2009) were reported as naturally occurring and/or below human health and ecological screening values. There is likely no contamination present.

During the RI, no MEC or MD constituting an MC source (for criteria, see **Section 0**) were observed, analyzed, or assessed; therefore, a discussion of contaminant persistence is not relevant.

5.2.2.6 MC EXPOSURE CONCLUSIONS

Based on the number of current and previous field investigations, particularly the SI (Shaw, 2009) and the 2013 RI field investigation, the potential for human and ecological exposure to MC is likely very low. There is some degree of uncertainty associated with other MEC items (source of MC) which remain buried (if any). However, all information to date suggests that the soil exposure pathway for human receptors for MC is potentially complete at the Range Complex No. 1 MRS (**Figure 5-20**) and likely incomplete for Range Complex No. 1 (a) and Range Complex No. 1 (b) (**Figure 5-21** and **Figure 5-22**, respectively). Range Complex No. 1 (a) and Range Complex No. 1 (b) MRSs are no longer being considered as potentially impacted by MC.

There was no evidence of leaking MC associated with the MEC items recovered from MRS Range Complex No. 1. Consequently, contamination of soil and other environmental media is unlikely and no soil samples were collected for chemical analysis. For MRS Range Complex No. 1, some exposure pathways are potentially complete though likely insignificant simply because MEC was found and other MEC could possibly be present. Based on the absence of MEC at the other two MRSs, all MC exposure pathways are likely incomplete.

There is likely no potential for unacceptable exposure to MC anywhere for ecological receptors at the Port Angeles Range Complex MRSs. **Figure 5-23**, **Figure 5-24**, and **Figure 5-25** present the updated CSMs for ecological receptors. If damaged MEC were present (currently an unknown situation), MC could potentially be released to the environment. The potential for MC releases appears to be low based on the limited locations of the MEC recovered in MRS Range Complex No. 1 and the lack of MEC recovered elsewhere.

Figure 5-20 Updated Conceptual Site Model for MC Exposure to Human Receptors at the Port Angeles MRS Range Complex No. 1

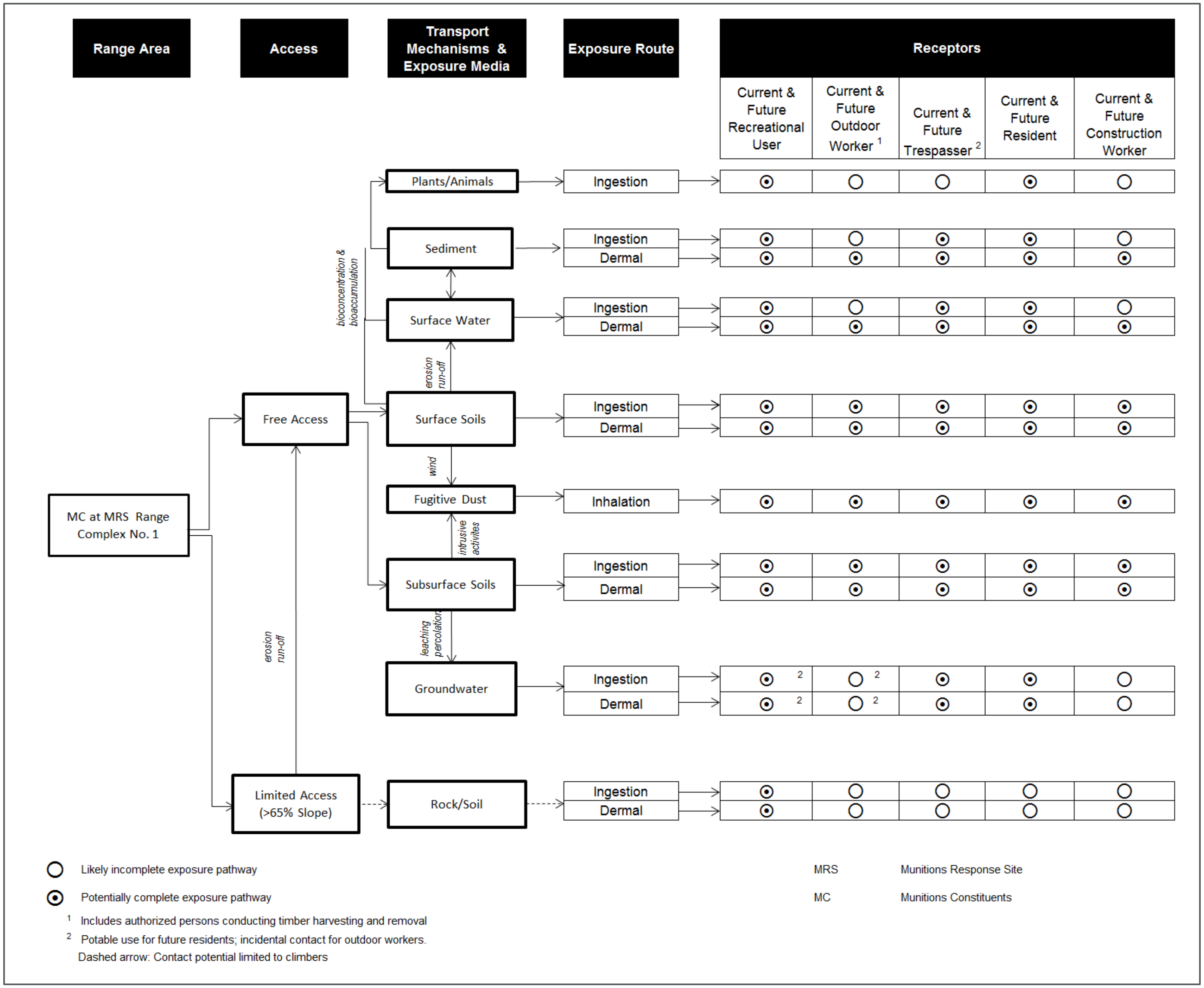
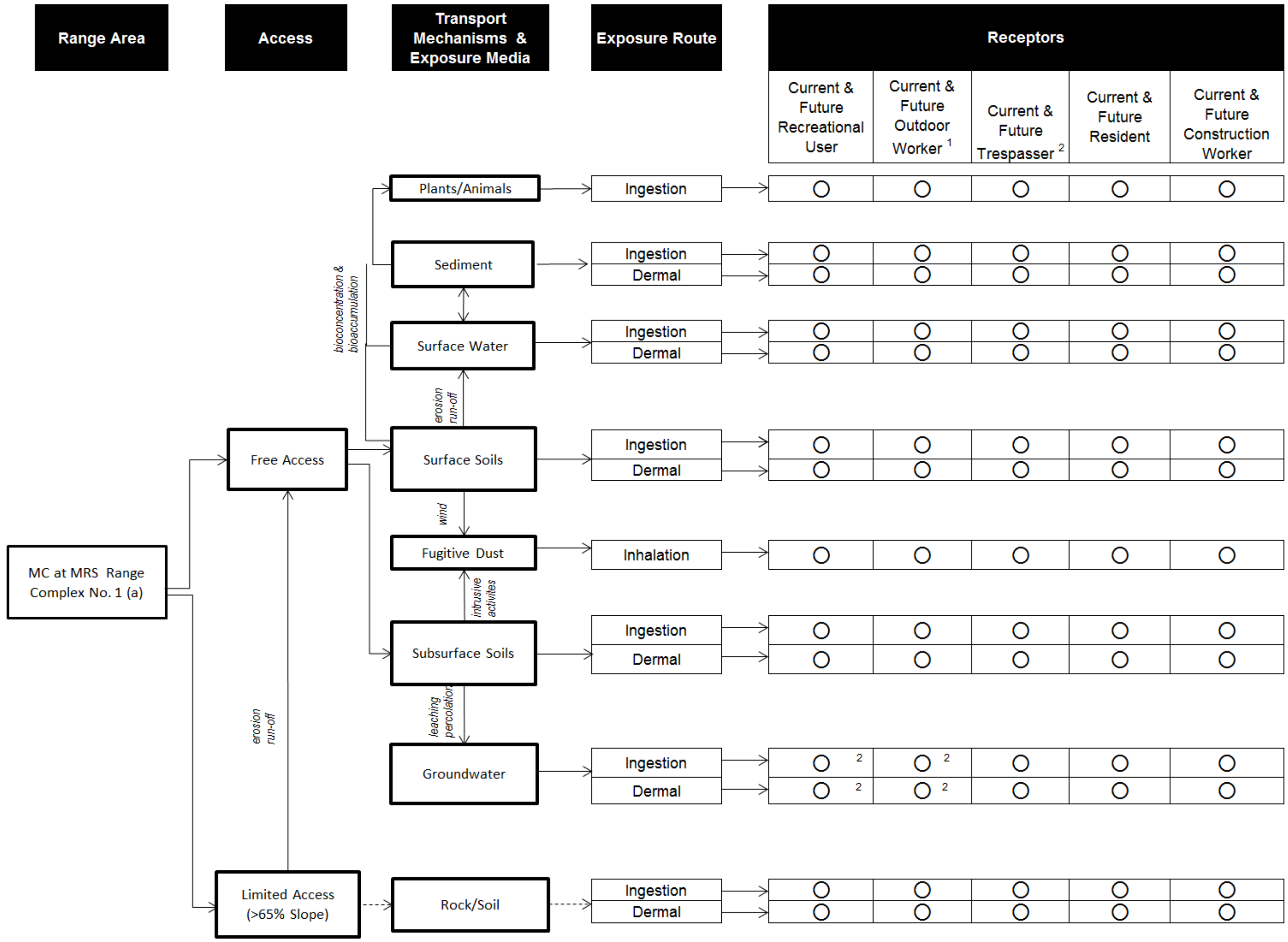


Figure 5-21 Updated Conceptual Site Model for MC Exposure to Human Receptors at the Port Angeles MRS Range Complex No. 1 (a)



○ Likely incomplete exposure pathway

[1] Includes authorized persons conducting timber harvesting and removal

[2] Potable use for future residents; incidental contact for outdoor workers.

Dashed arrow: Contact potential limited to climbers

MRS Munitions Response Site

MC Munitions Constituents

Figure 5-22 Updated Conceptual Site Model for MC Exposure to Human Receptors at the Port Angeles MRS Range Complex No. 1 (b)

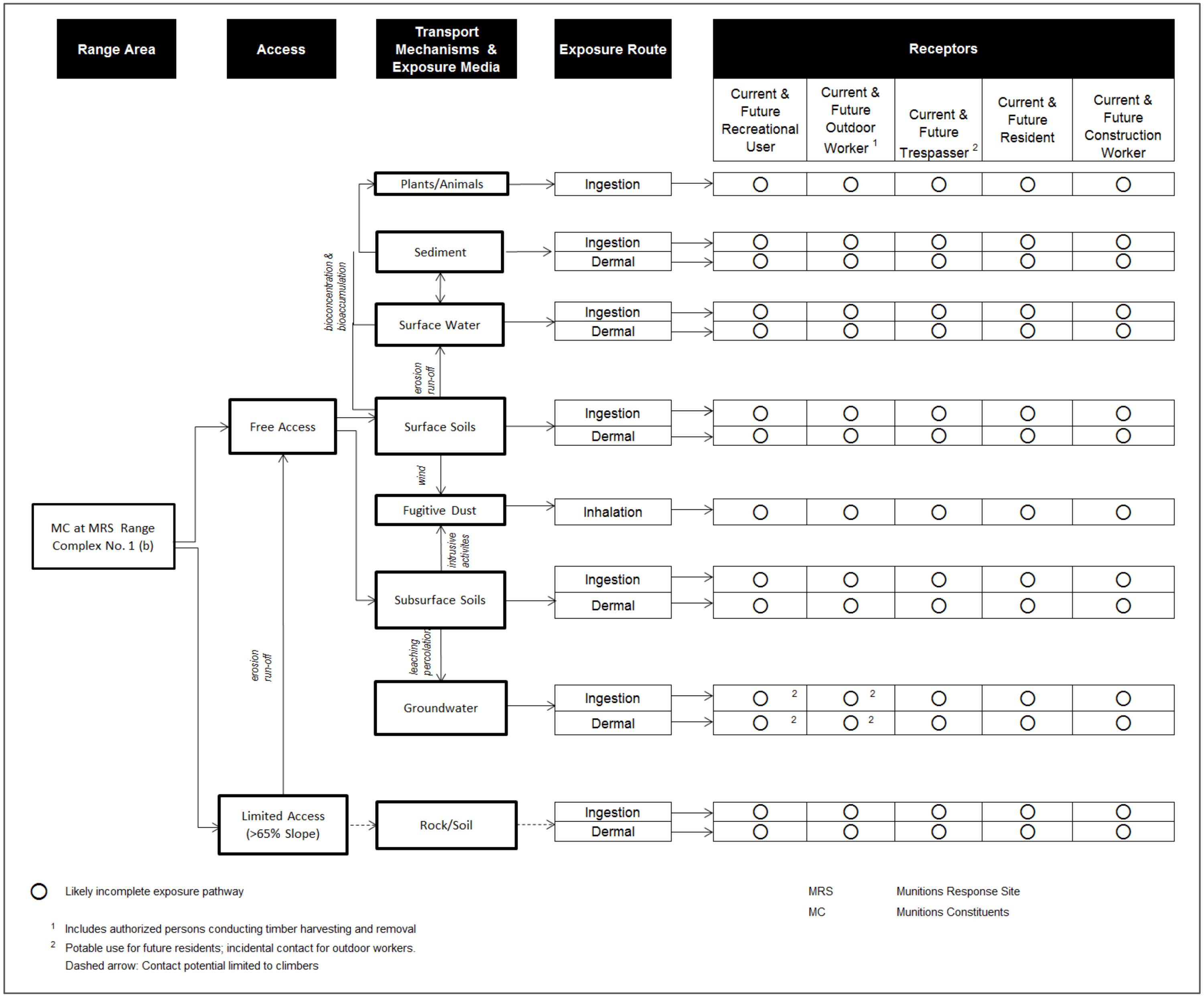


Figure 5-23 Updated Conceptual Site Model for MC Exposure to Ecological Receptors at the Port Angeles MRS Range Complex No. 1

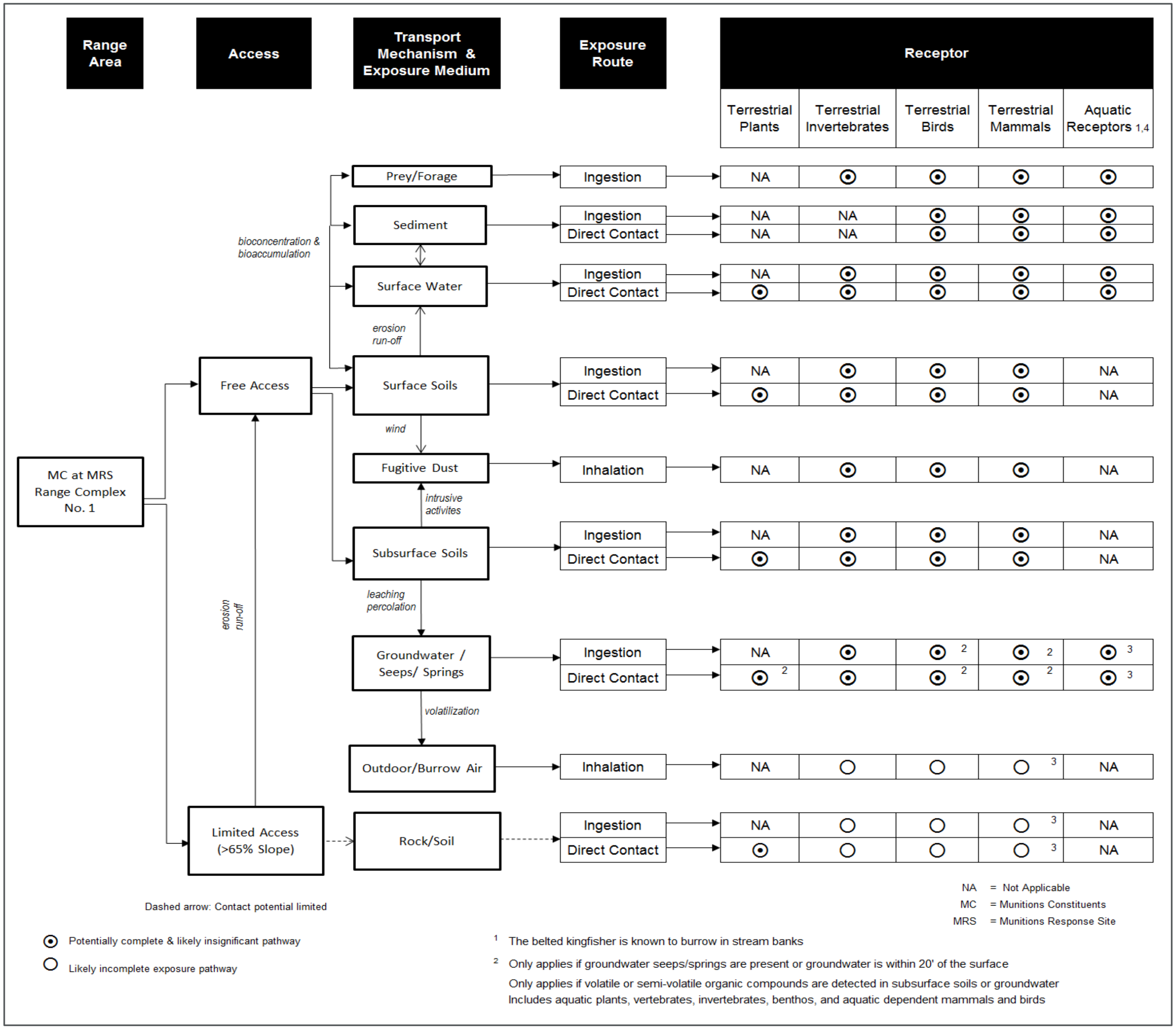


Figure 5-24 Updated Conceptual Site Model for MC Exposure to Ecological Receptors at the Port Angeles MRS Range Complex No. 1 (a)

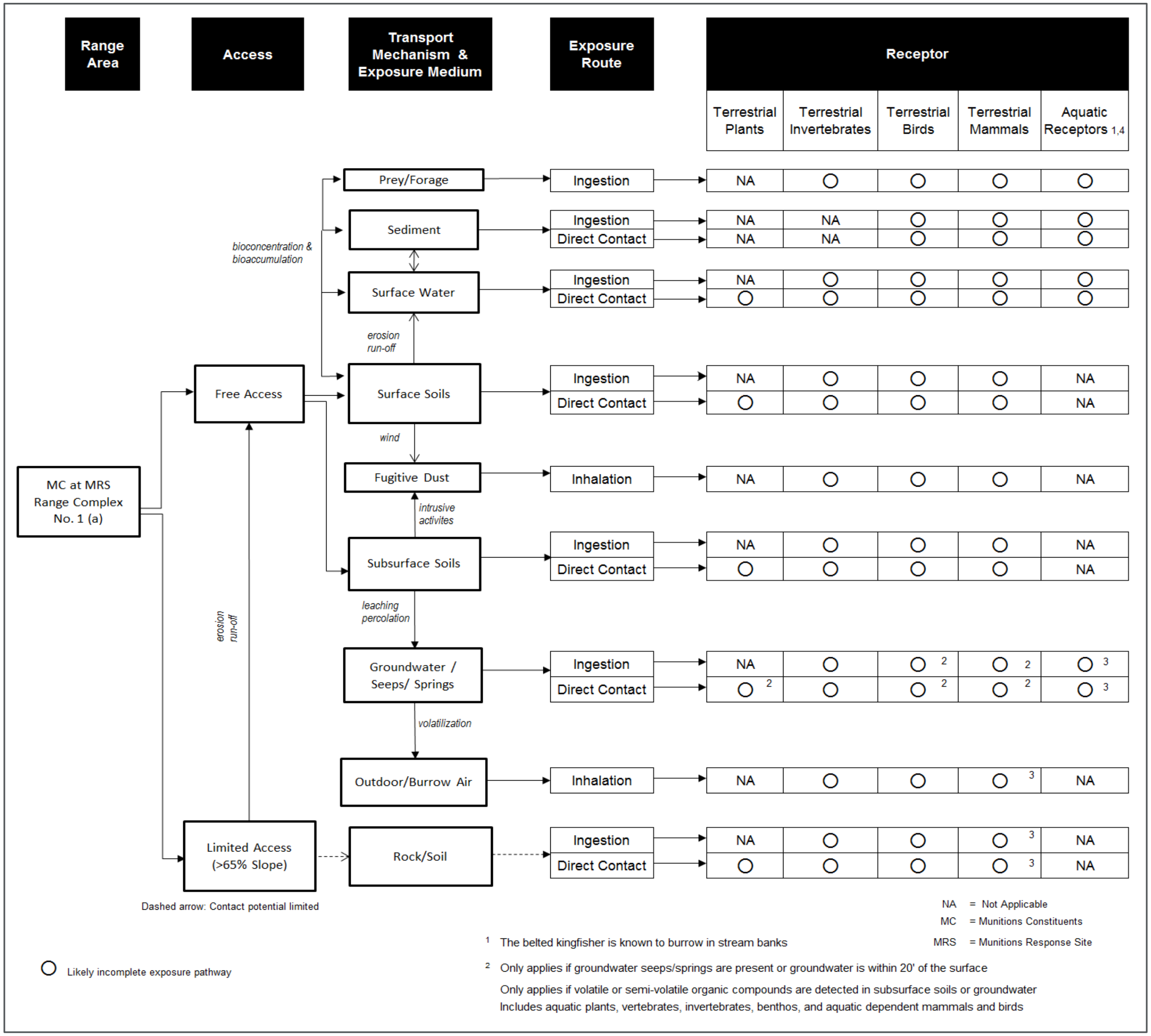
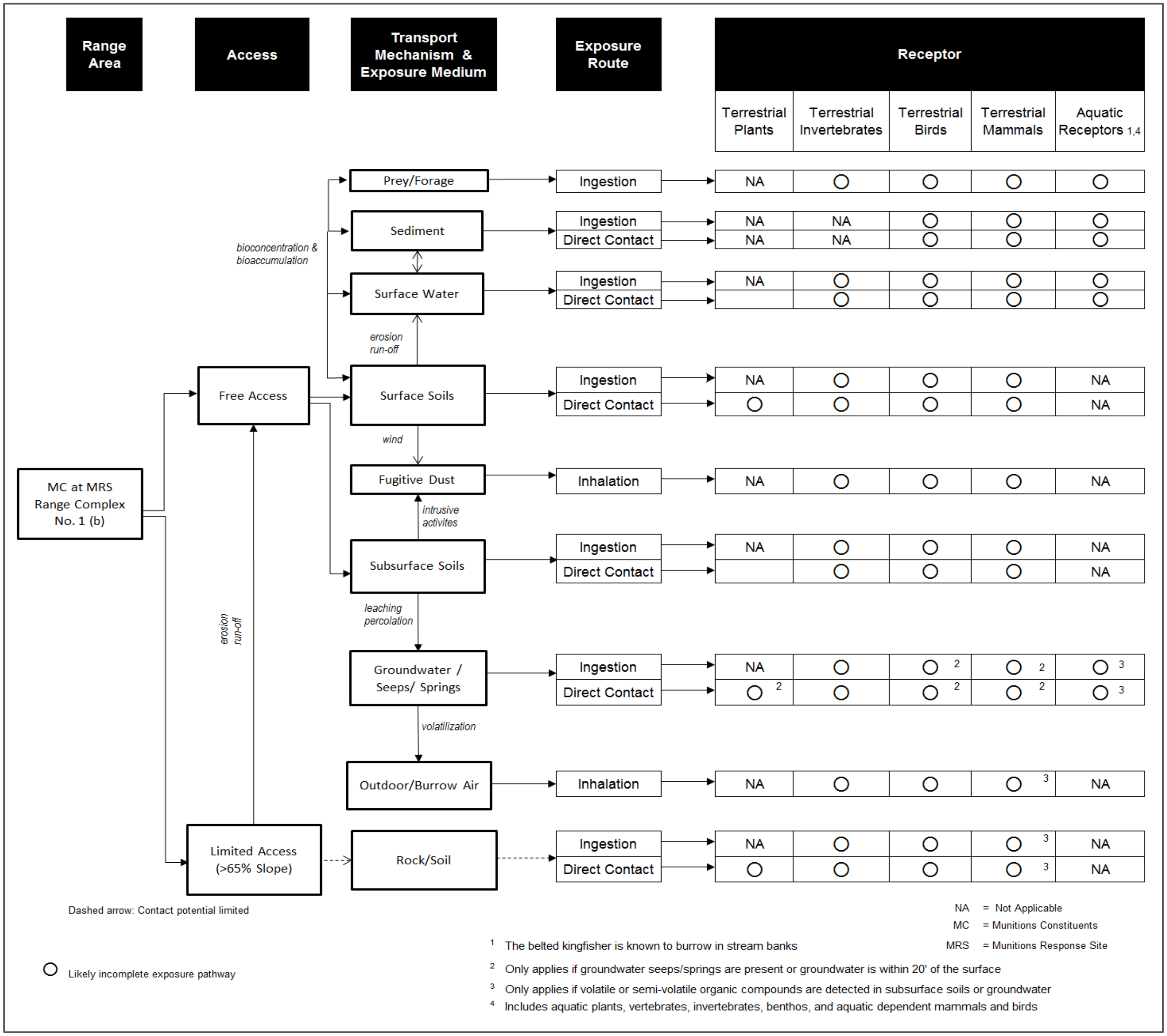


Figure 5-25 Updated Conceptual Site Model for MC Exposure to Ecological Receptors at the Port Angeles MRS Range Complex No. 1 (b)



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6.0 Contaminant Fate and Transport for MEC and MC

The MEC items discovered during the RI did not represent potential sources of MC. However, only 10% of each grid was investigated during the RI; therefore, there is still potential for MEC and MC at Range Complex No. 1.

6.1 Munitions and Explosives of Concern

There is the potential for human and ecological receptors to access MEC at the MRSs in surface and subsurface soil. Five MEC items were found during the RI field activities; consequently, all soil exposure pathways for access and exposure to MEC in these MRSs are complete for all receptors. Based on the recovery of semi-buried MEC items (i.e., the M63 37mm HE projectiles at grids K-03 and M-11), surface soil exposure pathways to MEC remain complete. All recovered MEC items were located in shallow surface soil (0-6 inches bgs). MD were present in many areas which suggests that other MEC may be present but not visible. No CWM or evidence of CWM was observed within the MRSs.

In general, the potential for transport of MEC from one location to another is based on the amount of precipitation, stabilization in soil, the steepness of the slope, and weight of the item. In areas that have steep, open slopes, MEC could be transported via frost heave and erosion or possibly by mudslides depending on the slope and cover. There are surface water features in the Range Complex No. 1 MRS; therefore, MEC transport from initial source locations to surface water or sediment and other areas within this MRS is possible although unlikely. Over time, soils, rocks, and organic debris tend to accumulate around stationary items thereby inhibiting movement. Due to the lack of ROE, Range Complex No. 1 (b) was not investigated during the RI.

6.2 Munitions Constituents

MEC can potentially represent a source of MC, specifically explosive residues in the form of nitroaromatics and nitramines. Migration of explosive residues can occur primarily from precipitation and fugitive dust. It is more likely that snowmelt and rainfall rather than fugitive dust would mobilize explosive residues from their initial source location. Windblown dust represents a potential migration pathway but a minor one relative to transport by moisture. MC can be found in subsurface soils upon initial deposition. However, many energetics are more likely to bind to humic materials where present, thereby limiting further leaching.

Based on the number of current and previous field investigations, particularly the SI (Shaw, 2009) and the 2013 RI field investigation, the potential for human and ecological exposure to MC is likely very low. There is some degree of uncertainty associated with other MEC items (source of MC) which remain buried (if any). However, all information to date suggests that the soil exposure pathway for human receptors for MC is potentially complete at the Range Complex No. 1 MRS and likely incomplete for Range Complex No. 1 (a) and Range Complex No. 1 (b).

There was no evidence of leaking MC associated with the MEC items recovered from MRS Range Complex No. 1. Consequently, contamination of soil and other environmental media is unlikely and no soil samples were collected for chemical analysis. For MRS Range Complex No. 1, some exposure pathways are potentially complete though likely insignificant simply because MEC was found and other MEC could possibly be present. Based on the absence of MEC at the other two MRSs, all MC exposure pathways are likely incomplete.

MC released from MEC could be transported by surface water runoff to other areas down gradient from the source. MC could migrate to groundwater only in areas where depth to groundwater is shallow or where a hydrogeological connection exists between groundwater and surface water. However, because seeps and springs were not observed within the Range Complex No. 1 MRS migration of MC to groundwater and surface water is likely negligible. Exposure to MEC and/or MC via frost heave and erosion is possible especially in steep ravines.

Heavy rainfall and snowmelt could mobilize MC residues from their initial source location. Windblown fugitive dust represents a potential migration pathway. MC can also be found in subsurface soils upon initial deposition or through vertical and horizontal migration.

MC can also migrate through uptake via the food chain. Mobile receptors can carry contaminants from source locations to other areas based on their home ranges and foraging areas.

There is the potential for human and ecological receptors including wildlife, and other biota to access MC in surface and subsurface soil in the Range Complex No. 1 MRS where MEC and MD was recovered. MC in surface soil results in potential for uptake by vegetation; thus, the food chain pathway is considered potentially complete though likely insignificant for human receptors, wildlife and other biota. Potentially complete food chain exposures are present for terrestrial and aquatic-dependent animals; the food chain pathway is complete though likely insignificant for terrestrial soil invertebrates.

7.0 Baseline Risk Assessment for MC and Hazard Assessment for MEC

Baseline human health and ecological risk assessments for this RI were limited since environmental soil sampling was not conducted during the RI. Only the SI data were available for consideration (Shaw, 2009); however these data were previously screened for human health and environmental concern and were less than screening levels and not addressed further in this RI.

There were limited MEC items found and no evidence of MC release. A MEC HA, however, has been included in **Section 7.3**.

7.1 Baseline Human Health Risk Assessment

A comprehensive, detailed quantitative baseline HHRA was not conducted for the PACR MRSs due to the absence of environmental sampling data from the RI.

7.1.1 Data Evaluation and Usability

During the RI, a limited amount of in-situ XRF data was collected for lead analysis. These data were only used qualitatively by the field investigation. The XRF would have been utilized to guide the locations of samples for laboratory analysis if they would have been required. The XRF analysis results were not considered definitive data and are no longer considered in the baseline HHRA.

7.1.2 Human Health Screening Levels for Contaminants of Potential Concern

Not applicable. Screening for contaminants of potential concern was not conducted.

7.1.3 Screening for Contaminants of Potential Concern

Screening for contaminants of potential concern was not conducted.

7.1.4 Uncertainty Analysis

An uncertainty analysis was not conducted.

7.1.5 Exposure Assessment

An exposure assessment was not conducted.

7.1.6 Toxicity Assessment

A toxicity assessment was not conducted.

7.1.7 Risk Characterization and Uncertainty Analysis

A risk characterization and uncertainty analysis was not conducted.

7.2 Baseline Ecological Risk Assessment

A BERA was not conducted for the Range Complex No. 1 MRS due to the absence of RI environmental sampling data.

7.2.1 Screening for Contaminants of Potential Ecological Concern

Not applicable. Screening for contaminants of potential concern was not conducted.

7.2.2 COPEC Screening Values

Screening for contaminants of potential concern was not conducted.

7.2.3 COPEC Screening Results

Screening for contaminants of potential concern was not conducted.

7.3 MEC Hazard Assessment

The MEC HA presented in this section follows the *Munitions and Explosives of Concern Hazard Assessment Methodology* (USEPA, 2008), which provides an assessment of the acute explosive hazards associated with remaining MEC at an MRS by analyzing site-specific conditions and human issues that affect the likelihood that a MEC accident will occur. The MEC HA method focuses on hazards to human receptors and does not directly address environmental or ecological concerns that might be associated with MEC. The process uses input data based on historical documentation, field observations, and the results of previous studies and removal actions. The MEC HA interim guidance was developed by the Technical Working Group for Hazard Assessment, which included representatives from the DoD, the U.S. Department of the Interior, the USEPA, and various states and tribes. The DoD has encouraged use of this method on a trial basis (DoD, 2009).

The MEC HA supports hazard communication among stakeholders by organizing site information in a consistent manner for the hazard management decision-making process. However, the MEC HA does not provide a quantitative assessment of MEC hazards and is not used to determine whether further action is necessary at a site. The MEC HA itself was performed using the *Excel®-based automated MEC HA workbook V. 1.02*.

The MEC HA method reflects the basic difference between assessing acute hazards from exposure to MEC and assessing chronic environmental risks from exposure to potential contaminants, such as MC. An explosive hazard can result in immediate injury or death; therefore, risks from explosive hazards are evaluated as either being present or not present. If the potential for an encounter with MEC exists, then the potential that the encounter may result in injury or death also exists. Conversely, if the potential presence of MEC at an MRS can be ruled out because of field investigations, then no explosive hazards are present, and a MEC HA is not necessary. However, it is very unlikely that explosive hazards at the PACR can be confirmed as nonexistent, so the MEC HA should reflect the level of uncertainty remaining.

The MEC HA is designed primarily for use at two points in the CERCLA process. The first point is at the end of an RI to assess baseline explosive hazards and provide information about the relative hazard reductions associated with remedial response alternatives that might be evaluated in the FS. The second point is at the end of a removal action to assess baseline explosive hazards and relative hazard reductions associated with removal. For the three recommended MRSs shown in **Figure 8-1** and described in **Section 8.5.1**, the MEC HA was performed to assess the baseline explosives hazard based on the RI results and hazards remaining after implementing possible remedial response alternatives. These baseline evaluations provide input for the evaluation and implementation of effective management response alternatives in the FS.

The MEC HA baseline evaluation (row "a" in **Table 7-5**) is equivalent to the NA alternative discussed in the FS (**Section 10.2.1**). The complete MEC HA tables and figures for each MRS are provided in **Appendix L**.

7.3.1 Overview of MEC Hazard Assessment Input Factors

The MEC HA is structured around three components of potential explosive hazard incidents:

- Severity, which is the potential consequences of the effect on a human receptor should a MEC item detonate.
- Accessibility, which is the likelihood that a human receptor will be able to come in contact with a MEC item.
- Sensitivity, which is the likelihood that a human receptor will be able to interact with a MEC item such that it will detonate.

Each of these components is assessed in the MEC HA by input factors. Each input factor has two or more categories, each associated with a numeric score that reflects the relative contributions of the different input factors. The sum of the input factor scores falls within one of four defined ranges, called Hazard Levels. Each of the four Hazard Levels reflects attributes that describe groups of MRSs and site conditions ranging from the highest to lowest hazards. The MEC HA scores should not be interpreted as quantitative measures of explosive hazard.

To complete the baseline MEC HA for each assessment area, the input factors are reviewed and suitable categories (baseline, surface MEC cleanup, or subsurface MEC cleanup) are selected based on historical documentation and field observations.

The input factors for the MEC HA method are described below (USEPA, 2008c):

Energetic Material Type: This factor describes the general type of energetic material associated with the munition(s) known or suspected to be present within the MRS or assessment area. The six possible categories for this factor, ranging from the most to least potentially hazardous, are:

- Low explosive fillers in fragmenting rounds
- White phosphorus
- Pyrotechnics
- Propellants
- Spotting charges
- Incendiaries

The category selected for each MRS or assessment area is based on the energetic material with the greatest potential explosive hazard known or suspected to be present.

Location of Additional Human Receptors: Human receptors other than the individual who causes a detonation may be exposed to overpressure and/or fragmentation hazards from the detonation of MEC. This factor describes whether or not there are additional human receptors located within the MRS/assessment area or within the explosive safety quantity-distance (ESQD) ARC surrounding the MRS/assessment area. The two possible categories for this factor are "inside the MRS or inside the ESQD arc surrounding the MRS" and "outside the ESQD arc".

Site Accessibility: The site accessibility factor describes how easily human receptors can gain access to the MRS or assessment area and takes into account the various barriers to entry that might be present. The four possible categories of site accessibility range from “full accessibility” (i.e., a site with no barriers to entry) to “very limited accessibility” (i.e., a site with guarded chain link fences or terrain that requires special skills and equipment to access). This factor differs from the Potential Contact Hours factor (see below) and does not include or account for LUCs that might restrict site access. The effects of LUCs are assessed in the FS alternatives assessment.

Potential Contact Hours: This factor accounts for the amount of time receptors spend within the MRS or assessment area during which they might come into contact with MEC and intentionally or unintentionally cause a detonation. Both the number of receptors and the amount of time each receptor spends in the MRS/assessment area are used to calculate the total “receptor-hours/year”. This total is calculated for all activities that might result in potential MEC interaction and there are four possible categories:

- Many hours, ≥ 1,000,000 receptor-hours/year.
- Some hours, 100,000 to 999,999 hours/year.
- Few hours, 10,000 to 99,999 hours/year.
- Very few hours, < 10,000 receptor-hours/year.

Amount of MEC: This input factor describes the relative quantity of MEC anticipated to remain within the MRS or assessment area as a result of past munitions-related activities. For example, a greater quantity of MEC would be expected to be present in a former target area than at a former firing point. The nine possible categories for this factor, from the largest to the least anticipated amount of MEC, include “target area”, “Open Burn/Open Detonation (OB/OD) area,” “function test range”, “burial pit”, “maneuver areas”, “firing point,” safety buffer areas, “storage”, and “explosives-related industrial facility.”

Minimum MEC Depth Relative to the Maximum Receptor Intrusive Depth: This factor indicates whether the MEC in the MRS or assessment area are located at depths that might be reached by the anticipated human receptor activities. For the baseline MEC HA, the four possible categories concern whether or not MEC are located at the surface and in the subsurface within the MRS or assessment area, or whether MEC are present in the subsurface only, and whether or not the receptor intrusive depth overlaps with this MEC location.

Migration Potential: The migration potential factor addresses the likelihood that MEC in the MRS or assessment area might migrate by natural processes (e.g., erosion or frost heave) thereby increasing the chance of subsequent exposure to potential human receptors. The two possible categories for this factor are “possible” and “unlikely”.

MEC Classification: This factor accounts for how easily a human receptor might cause a detonation of the MEC and relates directly to the MEC sensitivity. The six possible categories for this factor, ranging from the highest to lowest sensitivity (and explosive hazard) are:

- Sensitive UXO
- Other UXO
- Fuzed sensitive DMM
- Fuzed DMM
- Unfuzed DMM
- Bulk explosives

The selection of category for each MRS or assessment area is made using the MEC with the highest potential sensitivity known or suspected to be present and, where uncertainty exists; conservative assumptions are made and documented. For example, UXO is always assumed to be present within a known target area, whether or not the investigation uncovers UXO at the site.

MEC Size: This factor indicates how easy it is for a typical human receptor to move the MEC item(s) present within the MRS or assessment area. For example, an individual is considerably more likely to pick up or accidentally kick a hand grenade than a 200-lb bomb. The basic assumption used in this category is that MEC weighing 90-lbs or more is unlikely to be moved without the use of special equipment. Based on this assumption, the two possible categories for this factor are “small” (i.e., items weighing less than 90-lbs.) and “large” (items weighing 90-lbs or more). The selection of category for each MRS or assessment area is based on the MEC known or suspected to be present with the highest potential to be moved (i.e., the smallest item).

Each category for each of the MEC HA input factors has an assigned score that relates to the relative contributions of the different input factors to the overall MEC hazard. These scores were developed by the Technical Working Group for HA. These factors and their associated scores for the baseline condition are provided in (**Table 7-1**) while the detailed technical basis for the scores assigned is provided in the MEC HA interim guidance document (USEPA, 2008c). Scores for the categories are in multiples of five, with a total maximum possible score for all factors of 1,000 and a minimum possible score of 125. As previously noted, these MEC HA scores are *qualitative references only* and should not be interpreted as quantitative measures of explosive hazard. A summary of the maximum possible scores and their related weights with regard to the overall MEC HA score are shown in **Table 7-2**.

Table 7-1 Summary of MEC HA Input Factors and Associated Baseline Scores

Input Factor	Input Factor Category	Score after Subsurface Cleanup
Energetic Material Type	HE and low explosive fillers in fragmenting rounds	100
	White Phosphorus	70
	Pyrotechnic	60
	Propellant	50
	Spotting Charge	40
	Incendiary	30
Location of Additional Human Receptors	Inside the MRS or inside the ESQD arc surrounding the MRS	30
	Outside the ESQD arc	0
Site Accessibility	Full accessibility	80
	Moderate accessibility	55
	Limited accessibility	15
	Very limited accessibility	5
Potential Contact Hours	Many hours	30
	Some hours	20
	Few hours	10
	Very few hours	5
Amount of MEC	Target Area	30
	OB/OD area	30
	Function test range	25
	Burial Pit	10
	Maneuver Areas	5
	Firing Points	5
	Safety Buffer Areas	5
	Storage	5
	Explosive-related industrial facility	5
Minimum MEC Depth vs. Maximum Intrusive Depth	**Baseline Condition**: MEC located on surface and in subsurface; **After Cleanup**: intrusive depth overlaps with minimum MEC depth	95
	Baseline Condition: MEC located on surface and in subsurface; **After Cleanup**: intrusive depth *does not* overlap with minimum MEC depth	25
	Baseline Condition: MEC located only in subsurface; **Baseline Condition or After Cleanup**: intrusive depth overlaps with minimum MEC depth	95
	Baseline Condition: MEC located only in subsurface; **Baseline Condition or After Cleanup**: intrusive depth *does not* overlap with minimum MEC depth	25
Migration Potential	Possible	10
	Unlikely	10
MEC Classification	Sensitive UXO	
	UXO	
	Fuzed sensitive DMM	
	Fuzed DMM	
	Unfuzed DMM	
	Bulk explosives	
MEC Size	Small	40
	Large	0

Notes:
DMM – Discarded Military Munitions
ESQD – Explosive Safety Quantity-Distance
MEC – Munitions and Explosives of Concern
OB/OD – Open Burn/Open Detonation
UXO – Unexploded Ordnance

Table 7-2 Summary of MEC HA Maximum Scores and Weights

Explosive Hazard Component	Input Factor	Maximum Scores	Weights
Severity	Energetic Material Type	100	10%
	Location of Additional Human Receptors	30	3%
	Component Total	**130**	**13%**
Accessibility	Site Accessibility	80	8%
	Total Contact Hours	120	12%
	Amount of MEC	180	18%
	Minimum MEC Depth vs. Maximum Intrusive Depth	240	24%
	Migration Potential	30	3%
	Component Total	650	65%
Sensitivity	MEC Classification	180	18%
	MEC Size	40	4%
	Component Total	220	22%
	Maximum Total Score	**1,000**	**100%**

Notes:
MEC – Munitions and Explosives of Concern

7.3.2 MEC Hazard Assessment Input Data Summary

This MEC HA was conducted to evaluate the hazards at the three assessment areas (corresponding to the recommended MRSs) within the PACR (**Figure 7-1**). The delineation of the resulting MRSs was based on the types and quantities of MEC and MD found, and site conditions that suggest there were similar uses for the areas. These assessment areas follow the recommended MRSs described in **Section 8.5.1** as follows:

1. **MRS Range Complex No. 1** – This area represents the 105.7 acres where the five MEC items and 147 MD items were found. This MRS encompasses an area historically associated with a target range. There is one residence in this MRS. This MRS is recommended for further evaluation in the MEC-HA.
2. **MRS Range Complex No. 1 (a)** – This area of 1,286.5 acres represents a large portion (49%) of the original main range complex. No MEC or MD were found in this MRS. This MRS encompasses an area historically associated with a target range but includes buffer range as well. Based on the RI results this MRS is no longer believed associated with a target range. There are four residences in this MRS. This MRS is not considered for further evaluation in the MEC HA.
3. **MRS Range Complex No. 1 (b)** – This large area of 1,238.5 acres represents the buffer and impact/buffer zones within ONP where no ROE was obtained. Consequently, this MRS was not investigated during the RI. There are no humans residing within the ONP portion of the MRS. This MRS is not considered for further evaluation in the MEC HA.

The qualitative evaluation of explosive hazards was conducted by reviewing the input factors and developing specific inputs for each assessment area based on the RI findings, historical land use information, and available information about recreational and other users. The MEC HA evaluated the explosive hazards associated with the baseline, or current conditions, and hazards remaining after implementing possible remedial action alternatives to support evaluation of alternatives in the FS.

The baseline and post-remedial action conditions assume no change in access or use patterns. The area will continue to be used primarily for commercial forest management, watershed management, and limited recreation (typically hunting). Most of the PACR is privately owned and limited portions are used for recreation. There are currently no known plans to change access or limit land use for private property owners at the Range Complex No. 1 MRS where the MEC items were recovered.

The following paragraphs describe the input factors for each assessment area. The assessment areas used for the MEC HA are the recommended MRSs as shown in **Figure 8-1** which shows the locations of each MRS

7.3.2.1 ENERGETIC MATERIAL TYPE

The MEC items known or suspected to be present at each assessment area are based on the MEC and MD found within each area during the RI and previous clearance activities. MEC items found during the RI were destroyed following proper disposal practices; however, the MEC/MD found within each area are assumed to represent the types of munitions that may still be present, and were used to assess the hazards currently present and following implementation of the remedial action alternatives.

During the development of the RI Work Plan (HDR, 2013), the ESP included two possible MEC items, neither of which were actually recovered during the fieldwork. One of these items, an 81mm M45 mortar, was used to represent the most hazardous and sensitive item potentially present in the PACR per MEC HA guidance (USEPA, 2008). This selection was based on the horizontal fragmentation distance (HFD) of 242 feet for this item. The 75mm MK 1 projectile was also included in the MEC HA as potentially present at the PACR.

7.3.2.2 LOCATION OF ADDITIONAL HUMAN RECEPTORS

Additional human receptors potentially exposed to munitions present within each assessment area were evaluated based on the MEC and MD items found in each area. Net Explosive Weights, EQSD arcs (also referred to as HFDs), and total weights for all munitions are shown in **Table 7-3**.

Table 7-3 Net Explosive Weights, Hazardous Fragment Distances, and Total Weights for Munitions Found During the Port Angeles Combat Range Munitions Response Site Remedial Investigation

Munition	Nomenclature	Net Explosive Weight (lbs)	Explosive Type	Hazardous Fragmentation Distance (ft.)	Total Munition Weight, (lb.)
Mortar, 81mm	M45	4.48	TNT	242	8.40
Projectile, 75mm	MK1	1.64	TNT	239	11.20
Mortar, 81mm	M57	0.04	Tetryl and White Phosphorus	34	2.94
Mortar, 81mm	M43	1.23	TNT	209	5.45
Projectile, 37mm	M63	0.09	TNT	118	1.01

Notes:
mm – millimeter
TNT - Trinitrotoluene

Source: Department of Defense Explosives Safety Board (DDESB), April 2013.

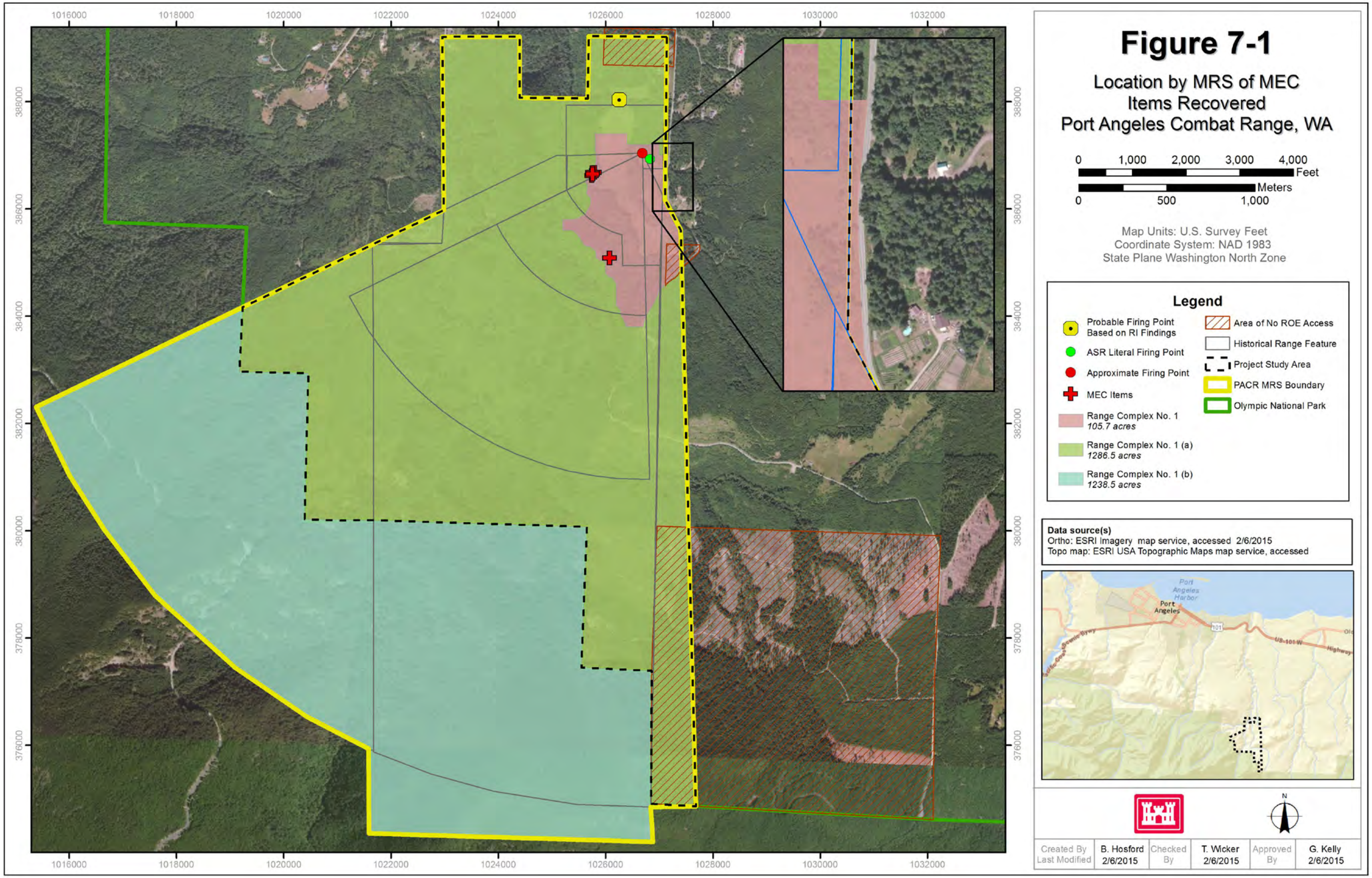
Figure 7-1
Location by MRS of MEC Items Recovered Port Angeles Combat Range, WA
0 1,000 2,000 3,000 4,000 Feet
0 500 1,000 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
Probable Firing Point Based on RI Findings
ASR Literal Firing Point
Approximate Firing Point
MEC Items
Range Complex No. 1 105.7 acres
Range Complex No. 1 (a) 1286.5 acres
Range Complex No. 1 (b) 1238.5 acres
Area of No ROE Access
Historical Range Feature
Project Study Area
PACR MRS Boundary
Olympic National Park
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed
Created By Last Modified B. Hosford 2/6/2015
Checked By T. Wicker 2/6/2015
Approved By G. Kelly 2/6/2015
1016000 1018000 1020000 1022000 1024000 1026000 1028000 1030000 1032000
388000 386000 384000 382000 380000 378000 376000

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7.3.2.3 RANGE COMPLEX NO. 1 MRS

The portion of the MRS impacted by MEC (4% of the site) will retain the Range Complex No. 1 designation. The MRS includes areas that were confirmed to be impact (target) areas based on the distribution of MEC/MD.

All five of the MEC items (i.e., M63 37mm HE projectiles) were found in this MRS. The most conservative HFD of 242 feet for an M45 81mm mortar was assumed to represent the EQSD arc for the Range Complex No. 1 MRS.

MD recovered as identifiable include:

- Thirteen M51 37mm AP projectiles
- One M48 75mm projectile, point detonating fuze (expended)
- One M44 81mm practice mortar
- Three M43A1 81mm HE mortar pieces
- Three M57 81mm WP mortar bodies
- Four 81mm mortar tail fin pieces
- One 81mm motor tail fin
- One 75mm practice projectile and one half of a 75mm projectile (empty)

The western boundary of the MRS is defined by the top of a steep unsurveyable ridgeline. The MRS boundary for this area was extended beyond the project boundary in the northeast (grids S-02 through S-06) so that future investigation, if any, occurs up to the existing Deer Park Road (to the east). This expansion increased the total project acreage to 2630.7 acres.

This Range Complex No. 1 MRS is 105.7 acres of which 3.4 acres were documented as unsurveyable due to dense vegetation and steep slopes. This unsurveyable acreage is unlikely to be included in any remedial action. An additional 3.9 acres of this MRS were not surveyed because the USACE did not receive an ROE for parcel 47501 (**Figure 2-3**).

7.3.2.4 SITE ACCESSIBILITY

Existing and dilapidated fences and signs may warn visitors of the historical use of munitions. Access to all three of the MRSs in general is limited primarily by steep terrain and dense vegetation. In particular, MRS site accessibility was categorized as moderate for MRS Range Complex No. 1 based on the limited number of roads, access points, and private property.

7.3.2.5 POTENTIAL CONTACT HOURS

Potential contact hours were estimated for the assessment areas based on limited information therefore, the estimates are uncertain. The area is sparsely populated. In addition, recreational use is primarily for hunting. There are many other locations within the ONP for recreational use; therefore, contact hours with potential MEC would likely be low in all cases. Information gathered during the RI fieldwork was limited to occasional observations and some conversations with local residents. Other information regarding use of the area came from the SI (Shaw, 2009) and the ASR (USACE, 1996).

Estimation of contact hours was obtained by assessing the general land use and the presence of residents on or near each MRS.

MRS Range Complex No. 1 – due to the small size of this area in relation to the range complex as a whole, and the presence of only one residence located at the southern end of the MRS, recreational use was assumed very limited. Vegetable gardening likely occurs only at the primary residence; no gardens were observed by the field teams but they may be present. Target shooting and hunting might occur, but due to the small size of the MRS and proximity to Deer Park Road, such activities are likely minimal (**Appendix L**).

Although limited, contact hours were estimated for recreational users during the height of the summer season, typically June through August (six hours/day, one weekend/month [two days], for three months/year). Hunters and trespassers could hike into the heavily forested areas off established roads and trails. Hunting may or may not be allowed on the City of Port Angeles land; however, the field teams noted the presence of field dressed and processed (i.e. gutted and meat harvested) deer carcasses from hunting activities during the fall hunting season. No hikers or campers were observed during the RI fieldwork. Specific documentation regarding the number of hunters that may use the area is unavailable due to the private land use. Contact hours were estimated assuming that hunters would be likely to spend up to six hours per day during the fall deer hunting season (assuming every weekend [two days] for a total of four months/year). All activities were assumed to occur in daylight only. The field team observed vehicles parked by the roadside and surmised that the hunters were driving in from nearby Port Angeles. Limited fishing and gardening were also assumed to occur since there are streams and a residence in the MRS (for details, refer to **Appendix L**).

Contact hours for the commercial forest management worker were estimated using an 8-hour workday for 30 days per year (**Appendix L**). Typical work activities might include tree clearance, road maintenance, and land clearing. Workers could perform intrusive activities for various maintenance and construction projects, and a maximum intrusive depth of five feet bgs was estimated to account for these types of activities.

7.3.2.6 AMOUNT OF MEC

The Range Complex No. 1 MRS was used for WWII combat training, and there was documentation of specific uses or locations of exercises. Based on descriptions of the training in the ASR (USACE, 1996)and the SI report (Shaw, 2009), firing points and targets were selected for individual exercises and records of the specific exercise locations were not kept. The sparse distribution of MEC/MD found throughout most of the area during the extensive AVS performed in 2013, with higher concentrations found within the Range Complex No. 1 MRS is consistent with this type of use as a target area.

7.3.2.7 MINIMUM MEC DEPTH RELATIVE TO THE MAXIMUM RECEPTOR INTRUSIVE DEPTH

All five MEC items were recovered from the surface soil interval (0.5-foot bgs). Leaf litter and some soil obscured visibility. Minimal effort was needed to recover each item.

The maximum intrusive depth assumed for site users was 0.5-foot bgs for recreational users and up to 5 feet bgs for forest and construction workers. Based on this information, the minimum MEC depth relative to the maximum receptor intrusive depth overlaps. This applies to both the current and future scenarios in all assessment areas.

7.3.2.8 MIGRATION POTENTIAL

Migration of surface or subsurface items is possible due to erosion, frost heave, or mudslide considering the elevation and some steep slopes present in the assessment areas. Frost heave could possibly expose buried MEC. This factor applies to all assessment areas for both current conditions and all post-remedial action scenarios.

7.3.2.9 MEC CLASSIFICATION

As noted in the energetic materials description, MEC items known or suspected to be present in Range Complex No.1 included 37mm artillery, 75mm artillery, 60mm mortars, and 81mm mortars.

7.3.2.10 MEC SIZE

The largest MEC and MD items suspected in the Range Complex No. 1 MRS, included 75mm artillery and 81mm mortars. None of these weighs more than 15 lbs (**Table 7-3**); thus, these MEC were classified as small items (less than 90 lbs).

7.3.3 Overview of MEC Hazard Assessment Output Factors

Once the categories and scores for all input factors are defined for each MRS or assessment area at the site, the related scores for each category are totaled to calculate an overall MEC HA score for each MRS/assessment area. The total maximum possible MEC HA score for an MRS/assessment area ranges from 125 - 1,000. The MEC HA method identifies the associated hazard levels for these scores, which can range from one to four. A Hazard Level of one indicates the highest potential explosive hazard conditions and a hazard level of four indicates low potential explosive hazard conditions. The basis for these hazard levels is detailed in the MEC HA interim guidance document (USEPA, 2008c). As previously noted, the total MEC HA scores and associated hazard levels are qualitative references only and should not be interpreted as quantitative measures of explosive hazard, or as the sole basis for determining whether or not further action is necessary at a site. A summary of the hazard levels and their related MEC HA scores are presented in **Table 7-4**.

Table 7-4 Hazard Level Scoring Ranks

Hazard Level	Maximum MEC HA Score	Minimum MEC HA Score	Associated Relative Explosive Hazard
1	1,000	840	Highest potential explosive hazard conditions
2	835	725	High potential explosive hazard conditions
3	720	530	Moderate potential explosive hazard conditions
4	525	125	Low potential explosive hazard conditions

7.3.4 MEC Hazard Assessment Outputs and Scorings

Hazard level determinations and scoring based on MEC HA remedial alternatives are presented for the one MRS in **Table 7-5** and **Table 7-6**. Scoring Summary “b”, Summary Scoring for Future Use, is not applicable, and is therefore not shown in the tables below.

Table 7-5 Port Angeles Range Complex No. 1 MRS MEC HA Hazard Level Determination

Alternative Description	Hazard Level Category	Score
Port Angeles Combat Range Complex No. 1 MRS		
a. Current Use Activities	2	780
b. Response Alternative 1: Institutional Controls	2	780
c. Response Alternative 2: Surface Removal	3	565
d. Response Alternative 3: Subsurface Removal	3	545
e. Response Alternative 4: Tree	3	545

Table 7-6 Range Complex No. 1 MRS: Alternatives 1, 2, 3, and 4, MEC HA Scores

Scoring Summary			
Port Angeles Combat Range - Range Complex No. 1 MRS			
Site ID:	**Port Angeles Combat Range FUDS Property No. F10WA00330**	**a. *Scoring Summary for Current Use Activities***	
Date:	**2/6/2015**	**Response Action Cleanup:**	**No Response Action**
Input Factor		**Input Factor Category**	**Score**
I. Energetic Material Type		High Explosive and Low Explosive Filler in Fragmenting Rounds	100
II. Location of Additional Human Receptors		Inside the MRS or inside the ESQD arc	30
III. Site Accessibility		Moderate Accessibility	55
IV. Potential Contact Hours		<10,000 receptor-hrs/yr	15
V. Amount of MEC		Target Area	180
VI. Minimum MEC Depth Relative to Maximum Intrusive Depth		Baseline Condition: MEC located only subsurface. Baseline Condition or After Cleanup: Intrusive depth overlaps with minimum MEC depth.	150
VII. Migration Potential		Possible	30
VIII. MEC Classification		UXO Special Case	180
IX. MEC Size		Small	40
		Total Score	**780**
		Hazard Level Category	**2**

Site ID:	**Port Angeles Combat Range FUDS Property No. F10WA00330**	***b. Scoring Summary for Response Alternative 1: Institutional Controls***	
Date:	**2/6/2015**	**Response Action Cleanup:**	**No MEC cleanup**
Input Factor		**Input Factor Category**	**Score**
I. Energetic Material Type		High Explosive and Low Explosive Filler in Fragmenting Rounds	100
II. Location of Additional Human Receptors		Inside the MRS or inside the ESQD arc	30
III. Site Accessibility		Moderate Accessibility	55
IV. Potential Contact Hours		<10,000 receptor-hrs/yr	15
V. Amount of MEC		Target Area	180
VI. Minimum MEC Depth Relative to Maximum Intrusive Depth		Baseline Condition: MEC located only subsurface. Baseline Condition or After Cleanup: Intrusive depth overlaps with minimum MEC depth.	150
VII. Migration Potential		Possible	30
VIII. MEC Classification		UXO Special Case	180
IX. MEC Size		Small	40
		Total Score	**780**
		Hazard Level Category	**2**

Table 7-6 Range Complex No. 1 MRS: Alternatives 1, 2, 3, and 4, MEC HA Scores (Continued)

Site ID:	**Port Angeles Combat Range FUDS Property No. F10WA00330**	***c. Scoring Summary for Response Alternative 2: Surface Removal***	
Date:	**2/6/2015**	**Response Action Cleanup:**	**cleanup of MECs located on the surface only**
I. Energetic Material Type		High Explosive and Low Explosive Filler in Fragmenting Rounds	100
II. Location of Additional Human Receptors		Inside the MRS or inside the ESQD arc	30
III. Site Accessibility		Moderate Accessibility	55
IV. Potential Contact Hours		<10,000 receptor-hrs/yr	10
V. Amount of MEC		Target Area	120
VI. Minimum MEC Depth Relative to Maximum Intrusive Depth		Baseline Condition: MEC located only subsurface. Baseline Condition or After Cleanup: Intrusive depth overlaps with minimum MEC depth.	N/A
VII. Migration Potential		Possible	30
VIII. MEC Classification		UXO Special Case	180
IX. MEC Size		Small	40
		Total Score	**565**
		Hazard Level Category	**3**

Site ID:	**Port Angeles Combat Range FUDS Property No. F10WA00330**	**d. Scoring Summary for Response Alternative 3: Subsurface Removal**	
Date:	**2/6/2015**	**Response Action Cleanup:**	**cleanup of MECs located both on the surface and subsurface**
I. Energetic Material Type		High Explosive and Low Explosive Filler in Fragmenting Rounds	100
II. Location of Additional Human Receptors		Inside the MRS or inside the ESQD arc	30
III. Site Accessibility		Moderate Accessibility	55
IV. Potential Contact Hours		<10,000 receptor-hrs/yr	5
V. Amount of MEC		Target Area	30
VI. Minimum MEC Depth Relative to Maximum Intrusive Depth		Baseline Condition: MEC located only subsurface. Baseline Condition or After Cleanup: Intrusive depth overlaps with minimum MEC depth.	95
VII. Migration Potential		Possible	10
VIII. MEC Classification		UXO Special Case	180
IX. MEC Size		Small	40
		Total Score	**545**
		Hazard Level Category	**3**

Table 7-6 Range Complex No. 1 MRS: Alternatives 1, 2, 3, and 4, MEC HA Scores (Continued)

Site ID:	Port Angeles Combat Range FUDS Property No. F10WA00330	e. Scoring Summary for Response Alternative 4: Tree Survey and Removal	
Date:	2/6/2015	Response Action Cleanup:	cleanup of MECs located both on the surface and subsurface
I. Energetic Material Type		High Explosive and Low Explosive Filler in Fragmenting Rounds	100
II. Location of Additional Human Receptors		Inside the MRS or inside the ESQD arc	30
III. Site Accessibility		Moderate Accessibility	55
IV. Potential Contact Hours		<10,000 receptor-hrs/yr	5
V. Amount of MEC		Target Area	30
VI. Minimum MEC Depth Relative to Maximum Intrusive Depth		Baseline Condition: MEC located only subsurface. Baseline Condition or After Cleanup: Intrusive depth overlaps with minimum MEC depth.	95
VII. Migration Potential		Possible	10
VIII. MEC Classification		UXO Special Case	180
IX. MEC Size		Small	40
		Total Score	**545**
		Hazard Level Category	**3**

7.4 Munitions Response Site Prioritization Protocol Update

This section discusses the updated Munitions Response Site Prioritization Protocol (MRSPP) for the PACR and the associated MRSs as a result of this RI.

The DoD proposed the MRSPP (32 Code of Federal Regulations [CFR] Part 179) (DoD, 2009) to assign a relative risk priority to each defense site in the MMRP Inventory for response activities. These response activities are based on the overall conditions at each MRS and consider various factors related to explosive safety and environmental hazards (68 FR 50900) (DoD, 2003). The application of the MRSPP applies to all locations:

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

In assigning a relative priority for response activities, the DoD generally considers MRSs posing the greatest hazard as being the highest priority. The MRSPP priority will be one factor in determining the sequence in which munitions response actions are funded.

The Range Complex No. 1 parent parcel MRS (i.e. the 2.629.8 acre MRS from the SI) was initially scored based on the worst-case of the components of the MRA at the conclusion of the SI. The Range Complex No. 1 parent parcel MRS scored a priority rating of 3 at the conclusion of the SI (Shaw, 2009) based on the Explosive Hazard Evaluation (EHE) and the Human Health Evaluation (HHE). No Chemical Warfare Materiel was identified. Human Health Hazards were identified (Shaw, 2009).

The RI informally splits the Range Complex No. 1 parent parcel MRS (i.e. the 2.629.8 acre MRS from the SI) into three separate MRSs. The three MRSs are shown in **Figure 8-1**.

The Range Complex No. 1 parent parcel MRS (i.e. the 2.629.8 acre MRS from the SI) is recommended to be expanded by 0.9 acres, to a total of 2,630.7 acres, and to be split into three MRSs as follows:

- **Range Complex No. 1** - This MRS includes the areas where DGM and subsurface investigations were performed. There is evidence of sub-surface MEC and MD that pose unacceptable human health risks. The original project MRS boundary is recommended to be expanded by 0.9 acres to the east to align the MRS boundary with Deer Park Road. This MRS has been assigned a score of **Priority 3,** based upon the EHE.
- **Range Complex No.1 (a)** – This MRS includes the remaining acreage of the investigation area included as part of this RI (i.e. the areas that were investigated but did not contain any evidence of MEC). There was no evidence of military activity, MD, MEC or MC contamination. It is unlikely that MEC or MD are present within this MRS based upon the firing point and range analysis discussed in **Section 5.2.1.4.3**. This MRS has been assigned an alternative rating of **No Known or Suspected Hazard**.
- **Range Complex No. 1 (b)** – This MRS includes all acreage that falls within the ONP. The MRS was not investigated because a programmatic agreement to conduct investigation and remedial actions between the NPS and the DoD does not exist. It is unlikely that MEC or MD are present within this MRS based upon the firing point and range analysis discussed in **Section 5.2.1.4.3**. This MRS has been assigned an alternative rating of **No Known or Suspected Hazard**.

Based on the results of the RI, the MRSPP has been updated to include scoring for the recommended MRSs (refer to **Section 8.5.1**). The MRSPP worksheets are provided in **Appendix M**.

7.4.1 Explosive Hazard Evaluation Module

The EHE module assesses the presence of known or suspected explosive hazards. The EHE module is composed of three factors, each of which has two to four data elements that are intended to assess the specific conditions at an MRS. Based on site-specific information, each data element is assigned a numeric score. The sum of these values is the EHE module score that is used to determine the corresponding EHE module rating. These factors are as follows:

- **Explosive Hazard**: which has the data elements Munitions Type and Source of Hazard
- **Accessibility**: which has the data elements Location of Munitions, Ease of Access, and Status of Property
- **Receptors**: which has the data elements Population Density, Population Near Hazard, Types of Activities/Structures, and Ecological and/or Cultural Resources

The EHE module worksheet tables are presented in **Appendix M** and summarized in **Table 7-7**, below.

Table 7-7 Summary of EHE Data Element Score

Factors	Range Complex No. 1	Range Complex No. 1 (a)	Range Complex No. 1 (b)
Explosive Hazard Factor	35	-	-
Accessibility Factor	33	-	-
Receptor Factor	16	-	-
EHE Combination Level	84	-	-
TOTAL EHE MODULE RATING	**B**	**NH**	**NH**

Notes:
EHE = Explosive Hazard Evaluation *NH = No known or Suspected Explosive Hazard* *- = No data available*
B = a score of 82-91 on a scale of 0-100 where 100 indicates the highest explosive hazard

7.4.2 Chemical Warfare Materiel Hazard Evaluation Module

The Chemical Warfare Materiel Hazard Evaluation (CHE) module provides an evaluation of the chemical hazards associated with the physiological effects of CWM. The CHE module is used only when CWM in the form of MEC or MC are known or suspected of being present at an MRA or MRS. Like the EHE module, the CHE module has three factors, each of which has two to four data elements that are intended to assess the conditions at an MRA or MRS. These factors are as follows:

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

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

The worksheet tables are presented in **Appendix M** and summarized in **Table 7-8**. There was no evidence of CWM at any of the MRSs.

Table 7-8 Summary of the CHE Data Element Score

Factors	Range Complex No. 1	Range Complex No. 1 (a)	Range Complex No. 1 (b)
CWM Hazard Factor	0	0	0
Accessibility Factor	0	0	0
Receptor Factor	0	0	0
CHE COMBINATION LEVEL	0	0	0
TOTAL CHE MODULE RATING	**NH**	**NH**	**NH**

Notes:
CWM = Chemical Warfare Materiel *CHE = Chemical Warfare Materiel Hazard Evaluation*
- = no data available *NH= No Known or Suspected CWM Hazard*

7.4.3 Health Hazard Evaluation Module

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

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

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

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

The worksheet tables are presented in **Appendix M** and summarized in **Table 7-9**.

Table 7-9 Summary of the HHE Surface Soil Data Element Score

Factors	Range Complex No. 1	Range Complex No. 1 (a)	Range Complex No. 1 (b)
Contaminant Hazard Factor	-	-	-
Migration Pathway Factor	-	-	-
Receptor Factor	-	-	-
HHE Combination Level	-	-	-
TOTAL HHE MODULE RATING	**Evaluation Pending**	**NH**	**NH**

Notes:
HHE = Human Health Evaluation *- = no data available* *NH = No Known or Suspected MC Hazard*
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7.4.4 Munitions Response Site Prioritization Protocol Score

In accordance with the DoD MRSPP Primer (DoD, 2007), each MRA and MRS is assigned an MRSPP Priority ranging from one to eight (**Table 7-10**). Priority 1 indicates the highest potential hazard and Priority 8 indicates the lowest potential hazard. Only a site with a chemical warfare hazard can receive an MRS Priority of one. The MRSPP Priority is determined by selecting the highest rating from among the EHE, CHE, and HHE modules. For example, if the EHE rating is two, the CHE rating is five, and the HHE rating is four, the MRSPP Priority assigned would be two. The

MRSPP Priority will be used to determine the future funding sequence of MRSs for further munitions response actions.

Table 7-10 Priority Ratings for the Port Angeles Combat Range Munitions Response Sites

Factors	Range Complex No. 1	Range Complex No. 1 (a)	Range Complex No. 1 (b)
EHE Module Rating	B	NH	NH
CHE Module Rating	NH	NH	NH
HHE Module Rating	Evaluation Pending	NH	NH
Priority	**3**	**NH**	**NH**

Notes:
CHE = Chemical Warfare Materiel Hazard Evaluation
EHE = Explosive Hazard Evaluation
HHE = Human Health Evaluation
NH = No Known or Suspected Hazard

8.0 Summary of Results

This summary describes the PACR RI and provides a review of the nature and extent of contamination delineated during the RI, a review of contaminant fate and transport, and a review of the risk assessment and qualitative MEC HA performed. It also presents conclusions derived from the results of the PACR RI.

The RI field activities at the PACR were conducted from mid-October to mid-December 2013. Field activities included AVS, in-situ XRF screening for MC (lead) in soil, geophysical surveys, and subsurface investigations. The results of the investigation are summarized in the following discussion. MEC and MD were identified during the RI. The high density of coverage during the AVS and geophysical surveys, and results of subsurface investigations have met the objectives of the RI to characterize the nature and extent of areas impacted by munitions related activities. The results provide sufficient information to make recommendations for further action, including recommending a large portion of the MRS for NDAI.

8.1 Nature and Extent of Contamination

The nature and extent of areas impacted by munitions related activities was defined based on the results of AVS, geophysical surveys, and subsurface investigations using mag and dig technology. Assisted visual surveys were performed during the RI. During the AVS, field teams surveyed virtually all of the accessible acreage in the MRS, walking a total of 112.1 miles of transects. The AVS team conducted real-time intrusive investigations on subsurface anomalies in areas where the use of DGM was not practical. DGM was not practical in areas with limited access, heavy vegetation, and steep topography. As shown in **Figure 5-1** through **Figure 5-3**, the surveys provided a high density of coverage in all accessible areas of the PACR. Due to cliffs or steep slopes, the presence of extensive areas of streams and/or dense vegetation, 567.8 acres of the PACR were unsurveyable and inaccessible. The USACE did not receive ROE for three parcels that overlapped the eastern PACR project boundary; consequently 105.9 acres were not surveyed. During the AVS, no features related to military activity were observed. Non-military site features encountered during the AVS included logging industry debris and civilian trash such as metal debris, metal cables, barbed wire, and old automobile wheel hubs.

During the subsequent subsurface investigations, 147 MD features were recorded in the Range Complex No. 1 MRS. Identifiable MD included; 13 M51 37mm AP projectiles, one M48 75mm projectile point detonating fuze (expended), one M44 81mm practice mortar, three M43A1 81mm HE mortar pieces, three M57 81mm WP mortar bodies, four 81mm mortar tail fin pieces, one 81mm motor tail fin, one 75mm practice projectile, and one half of a 75mm projectile (empty).

Twenty-five small arms debris features (20 unfired .50 caliber projectiles and five links) were recorded in the Range Complex No. 1 MRS. Due to the presence of the .50 caliber links and the lack of rifling striations it is believed the small arms were likely unfired and deposited in the area, as there are no indications of a separate small arms impact area.

Five MEC items were found during the RI field investigation within the Range Complex. No. 1 MRS. Four M63 37mm projectiles were discovered in grid K-03. In addition, eight pieces of HE frag, and two .50 caliber projectiles were found within grid K-03. One M63 37mm projectile was found within grid M-11.

No environmental sampling for MC analysis was performed during the RI because the conditions that would have warranted the collection of samples for laboratory analysis as described in **Section 4.2.1** were not observed during the field investigation. Environmental sampling for MC analysis was performed during the SI. There were no COPCs/COPECs associated with the HHRA and ecological screening of the soil, sediment, surface water, and groundwater data.

In-situ XRF screening for lead in soil was conducted during the RI in two locations where natural features (e.g., natural berm feature) were found, and in one location where small arms debris was found. Sixty-eight in-situ XRF screening locations were sampled in two natural features. Forty-five in-situ XRF screening locations were also sampled where small arms debris was found. A total of 113 in-situ XRF screening samples were collected from the three locations. All in-situ XRF screening sample results for lead were below the conservative screening level of 125 mg/kg (**Appendix J**). Thus, no soil samples were collected for laboratory analysis.

No MEC, MD, or small arms debris were found in areas of standing or flowing water. Therefore, no surface water or sediment samples were collected during the RI. No MEC, MD or small arms debris were found in saturated areas. Therefore, no groundwater sampling was conducted during the RI.

The nature and extent of the Port Angeles Combat Range is defined by the Range Complex No. 1 MRS boundary.

There was no evidence of MEC, MD, or MC contamination within Range Complex No. 1 (a). It is unlikely that MEC or MD are present within this MRS based upon the firing point and range analysis discussed in **Section 5.2.1.4.3**.

Range Complex No. 1 (b) is comprised of property within the ONP that was not investigated because a programmatic agreement to conduct investigations and remedial actions between the NPS and the DoD does not exist. It is unlikely that MEC or MD are present within this MRS based upon the firing point and range analysis discussed in **Section 5.2.1.4.3**.

8.2 Fate and Transport

There is the potential for human receptors to access MEC at the Range Complex No. 1 MRS in surface and subsurface soil. Five MEC items were found during the RI field activities; consequently, the surface soil exposure pathways for access and exposure to MEC are complete for all human receptors. Based on the recovery of the obscured MEC items in surface soil (i.e., the M63 37mm HE projectiles), subsurface soil exposure pathways to MEC are potentially complete. MD are present in many areas which suggests that other MEC may be present but not visible.

In general, the potential for transport of MEC from one location to another is based on the amount of precipitation, stabilization in soil, the steepness of the slope, and weight of the item. In areas that have steep, open slopes, MEC could be transported via frost heave and erosion or possibly by mudslides depending on the slope and cover. There are surface water features in the Range Complex No. 1 MRS; therefore, MEC transport from initial source locations to surface water or sediment and other areas within this MRS is possible although unlikely. Over time, soils, rocks, and organic debris tend to accumulate around stationary items thereby inhibiting movement. Due to the lack of ROE, Range Complex No. 1 (b) was not investigated during the RI.

The MEC items discovered during the RI did not represent potential sources of MC. However, only 10% of each grid was investigated during the RI; therefore, there is still potential for MEC and MC at Range Complex No. 1.

MEC can potentially represent a source of MC, specifically explosive residues in the form of nitroaromatics and nitramines. Migration of explosive residues can occur primarily from precipitation and fugitive dust. It is more likely that snowmelt and rainfall rather than fugitive dust would mobilize explosive residues from their initial source location. Windblown dust represents a potential migration pathway but a minor one relative to transport by moisture. MC can be found in subsurface soils upon initial deposition. However, many energetics are more likely to bind to humic materials where present, thereby limiting further leaching.

MC released from MEC could be transported by surface water runoff to other areas down gradient from the source. MC could migrate to groundwater only in areas where depth to groundwater is shallow or where a hydrogeological connection exists between groundwater and surface water. However, because seeps and springs were not observed within the Range Complex No. 1 MRS migration of MC to groundwater and surface water is likely negligible. Exposure to MEC and/or MC via frost heave and erosion is possible especially in steep ravines.

Heavy rainfall and snowmelt could mobilize MC residues from their initial source location. Windblown fugitive dust represents a potential migration pathway. MC can also be found in subsurface soils upon initial deposition or through vertical and horizontal migration.

MC can also migrate through uptake via the food chain. Mobile receptors can carry contaminants from source locations to other areas based on their home ranges and foraging areas.

There is the potential for human and ecological receptors including wildlife, and other biota to access MC in surface and subsurface soil in the Range Complex No. 1 MRS where MEC and MD was recovered. MC in surface soil results in potential for uptake by vegetation; thus, the food chain pathway is considered potentially complete though likely insignificant for human receptors, wildlife and other biota. Potentially complete food chain exposures are present for terrestrial and aquatic-dependent animals; the food chain pathway is complete though likely insignificant for terrestrial soil invertebrates.

8.3 Human Health and Ecological Risk Assessment

8.3.1 Baseline Human Health Risk Assessment

A baseline HHRA was not conducted for the MRSs due to the absence of environmental sampling data from the RI.

8.3.2 Baseline Ecological Risk Assessment

A BERA were conducted for the MRSs due to the absence of environmental sampling data.

8.4 MEC Hazard Assessment

The MEC HA was performed for three areas, consistent with the recommended MRS. The qualitative MEC HA analysis was performed for the current, or baseline conditions, as well as for several response alternative scenarios. The baseline and response alternative hazard level categories are summarized in **Table 8-1**.

Table 8-1 MEC HA Summary

Alternative Description	Hazard Level Category	Score
Port Angeles Range Complex No. 1 MRS		
a. Current Use Activities	2	780
b. Response Alternative 1: Institutional Controls	2	780
c. Response Alternative 2: Surface Removal	3	565
d. Response Alternative 3: Subsurface Removal	3	545
e. Response Alternative 4: Tree Survey and Removal	3	545

8.5 Conclusions

The PACR RI results are sufficient to achieve the RI objective to fully characterize the nature and extent of areas impacted by munitions within each MRS and provide information sufficient to evaluate remedial action alternatives and allow stakeholders to make an informed decision about the need for further action under the MMRP and CERCLA. The PACR parent MRS was informally separated into three MRSs based on the different levels of risk as determined by the types and distribution of MEC/MD. The RI results will be used to perform a FS to develop site-specific RAOs and remedial action alternatives appropriate to each MRS.

8.5.1 MRS Recommendations

It is recommended that the Range Complex No. 1 MRS be split into three MRSs as shown in **Figure 8-1**. These three MRSs reflect the information from historical records, AVS, geophysical surveys, the subsurface investigation, and in-situ XRF screening for lead in soil performed during the RI. These MRSs were developed based on the types and distribution of MEC/MD within each MRS and their recommended remedial action alternatives. These are also the same MRSs evaluated in the MEC HA. These areas are:

Range Complex No. 1 - The portion of the MRS impacted by MEC is recommended to be carried forward and retain the Range Complex No. 1 designation. The MRS includes the Direct Impact Fire Area (sub-range SR-02) and the adjacent Buffer Zones (sub-ranges SR-05, SR-04, and SR-07) (**Figure 8-1**) that were confirmed to be impact areas based on the results of the subsurface investigation and the distribution of MEC/MD. Five MEC items (M63 37mm HE projectiles) were recovered. Recovered identifiable MD included thirteen M51 37mm AP projectiles, one M48 75mm projectile point detonating fuze (expended), one M44 81mm practice mortar, three A1 81mm HE mortar pieces, three M57 81mm WP mortar bodies, four 81mm mortar tail fin pieces, one 81mm mortar tail fin, one 75mm practice projectile, and one half of a 75mm projectile (empty).

The top of a steep unsurveyable ridgeline defines the western boundary of the MRS. The MRS boundary for this area was extended beyond the project boundary in the northeast (grids S-02 through S-06) so that the MRS eastern boundary is located at the western edge of the existing Deer Park Road. This expansion added 0.9 acres to Range Complex No. 1 and increased the total project acreage from 2629.8 acres to 2630.7 acres.

This MRS contains MD and likely additional MEC and is 105.7 acres. 3.4 acres of this MRS were documented as unsurveyable due to dense vegetation, and steep slopes. 3.9 acres of this MRS were not investigated because the USACE did not receive a ROE for parcel 47501 (**Figure 2-3**).

Range Complex No. 1 (a) – The second MRS is designated Range Complex No. 1 (a). As described in **Section 5.1.1.3**, there was no evidence of military activity, MD, MEC or MC contamination.

This MRS is 1,286.5 acres and likely does not contain any MEC or MD based on the lack of evidence observed during the RI. Range Complex No. 1 (a) includes most of the area of Technical Approach Area 1 (Combat Training Area – sub-range R01-SR-06) in the northern portion of the MRS and Technical Approach Area 3 (Indirect Fire Impact Area – R-01-SR03 and adjacent Buffer Zones R01-SR-04, and R01-SR-07) in the southern portion of the MRS. The AVS that were conducted throughout the MRS indicate that it is unlikely that any impact areas or other significant features were missed. The areas that were able to be surveyed are within the direction of fire from the firing points to the targets further supporting the absence of munitions related items.

There were 564.4 acres of this MRS documented as unsurveyable due to dense vegetation, and steep slopes. In addition, 102.0 acres of this MRS were not surveyed because the USACE did not receive an ROE for Parcels 47404, 47501, and 47730 and (**Figure 2-3**).

Range Complex No. 1 (b) - The third MRS is designated Range Complex No. 1 (b). This 1,238.5 acre MRS is comprised of property within the ONP that was not investigated because a programmatic agreement to conduct investigation and remedial actions between the NPS and the DoD does not exist. It is unlikely that MEC or MD are present within this MRS based upon the firing point and range analysis discussed in **Section 5.2.1.4**.

Summary statistics for acreage, unsurveyable areas, and percentage of the original Range Complex. No.1 MRS for each of the recommended MRSs are presented in **Table 8-2**.

Table 8-2 Summary Statistics for Port Angeles Combat Range MRSs

Munitions Response Site	Area (Acres)	% Total Area	Unsurveyable Area (acres) No ROE	Unsurveyable Area (acres) Vegetation and Steep Terrain	Unsurveyable Area - Total (Acres)
Range Complex No. 1 MRS	105.7	4%	3.9	3.4	7.3
Range Complex No. 1 (a) MRS	1286.5	49%	102.0	564.4	666.4
Range Complex No. 1 (b) MRS	1238.5	47%	1238.5	0.0	1238.5
Total	**2630.7**[1]	**100%**	**1344.4**	**567.8**	**1912.2**

***Notes*:**
[1]*Total original MRS project acreage increased from 2629.8 acres to 2630.7 acres due to expansion of project boundary in Range Complex No. 1. The Range Complex No. 1 MRS project boundary was extended in the northeast (grids S-02 through S-06) so that future investigation occurs up to the west edge of the existing Deer Park Road.*
MRS = Munitions Response Site
ROE – Right of Entry

8.5.2 Data Limitations, Baseline Risk Assessment Analysis of Uncertainty, and Recommendations for Future Work

8.5.2.1 DATA LIMITATIONS

There are no significant data limitations after completion of the PACR RI field effort. The AVS, DGM and subsurface investigation were conducted in all accessible areas, and the inaccessible areas are likely inaccessible to any other site visitors or workers.

There is some uncertainty associated with the screening of the SI environmental media with the more current HHRA screening levels; however, these values are necessarily conservative. As such, they would tend to overestimate rather than underestimate potential risks.

8.5.2.2 REMEDIAL INVESTIGATION UNCERTAINTY EVALUATION

The AVS, geophysical surveys, subsurface investigations, evaluation of the MC, and the MEC and MD observed provided sufficient information to identify the impact area within the Range Complex No. 1 MRS. The VSP spatial evaluation of the potential for remaining target or impact areas that were not identified suggests there is a very low probability that there are unidentified target or impact areas within the MRS. This analysis was conducted only as a spatial analysis and was not intended to confirm detection of surface or subsurface munitions. The density of AVS and DGM coverage across all acreage except for unsurveyable areas also indicates that there is low potential for additional target areas outside of the Range Complex No. 1 MRS because there were no additional clusters of MEC or MD that would suggest a target area. The western boundary of the Range Complex No. 1 MRS was defined by the top of a steep unsurveyable ridgeline. Subsurface investigation grids were established and investigated directly adjacent to the top of the steep slope. Additional step out grids were not established due to the unsurveyable conditions. It is possible MEC may migrate down the slope, but human access to any potential MEC is likely insignificant due to the difficult inaccessible terrain. During the RI an attempt was made to survey the toe of the slope; however, it was also inaccessible.

Despite the density of coverage and a much more comprehensive understanding of how the area was used, there is still a potential for isolated MEC or MD to be present within the MRSs. Only a 100% surface and subsurface clearance could provide absolute assurance that there are no remaining hazards. There is potential for remaining subsurface MEC in the impact areas.

MC concentrations were below agreed upon screening values at the conclusion of the SI or were associated with naturally occurring soil concentrations. At that time, the stakeholders agreed that MC sampling would not be required for subsequent investigations (Shaw, 2009). No environmental sampling for MC analysis was performed during the RI because the conditions that would have warranted the collection of samples for laboratory analysis as described in **Section 4.2.1** were not observed during the field investigation. However, there is still a potential for MC release into the environment from damaged or leaking munitions. However, based on the SI analytical laboratory results and the amount and types of MD observed during the RI, it is unlikely that MC is a concern. The SI recommendation not to consider MC sampling during the RI, was valid. If damaged or leaking munitions items are found during future remedial actions, MC sampling may need to be evaluated.

There is uncertainty associated with the unknown site conditions within each MRS where no ROE was obtained. The uncertainty associated with each MRS is described below.

Range Complex No. 1

Due to no ROE, there is uncertainty associated with the unknown site conditions for 3.9 acres of parcel 47501 (**Figure 2-3**). MEC may be present within parcel 47501 given that MD (3 pieces of HE frag equaling less than 1 pound) was discovered in adjacent subsurface investigation grids (S-11 and S-12).

In addition, there is uncertainty associated with unknown site conditions in parcels 47420 and 47384, to the west of grid S-05. Based on the anomaly density analysis 119 grids were selected for subsurface investigation. An additional five grids were investigated as step out grids. Step out grids were established until the extent of munitions debris was determined. Complete delineation utilizing this methodology was achieved with the exception of grid S-05. Three small pieces of HE frag, weighing less than 0.25 lbs, were recovered in grid S-05 on the west side of Deer Park Road. No step out investigations were conducted to the east of Deer Park Road, as an ROE was not obtained for parcels 47420 and 47384. Numerous interviews in the ASR indicated that firing had taken place on the west side of the road (USACE, 1996). Based on the findings of the RI firing point and range analysis the direction of fire was determined to have been to the south (**Section 5.2.1.4.3**). Based on typical and historical range usage it is unlikely that munitions were fired towards the old school house or across the only access road to the MRS. Because of the range configuration and the limited amounts of MD the extent of potential MEC and MD is presumed to be to the west edge of Deer Park Road.

Range Complex No. 1 (a)

Due to no ROE, there is uncertainty associated with the site conditions for 102.0 acres within parcels 47404 and 47730 (**Figure 2-3**). It is unlikely that MEC or MD are present within this MRS based upon the firing point and range analysis discussed in **Section 5.2.1.4.3**. If a remedial action is selected during the subsequent PP/DD, the USACE will notify land owners and attempt to request a ROE.

Range Complex No. 1 (b)

Due to no ROE, there is uncertainty associated with the site conditions present at Range Complex No. 1 (b). This 1238.5-acre MRS is comprised of property within the ONP that was not investigated because a programmatic agreement to conduct investigations and remedial actions between the NPS and the DoD does not exist. It is unlikely that MEC or MD are present within this MRS based upon the firing point and range analysis discussed in **Section 5.2.1.4.3**.

8.5.3 Munitions Response Site Prioritization Protocol Update

The MRSPP was updated to reflect the RI results for the three recommended MRSs. The priority ratings are summarized in **Table 8-3**.

Table 8-3 MRSPP Summary

	Range Complex No. 1	Range Complex No. 1 (a)	Range Complex No. 1 (b) (Olympic National Park)
Priority	3	NH	NH

Notes:
NH = No Known or Suspected Hazard

8.5.4 FUDS Management Information System

The FUDS Management Information System (FUDSMIS) is used to track and report FUDS property, project, and phase data. It also supports planning, programming, and budgeting for FUDS sites. Upon final approval of the MRS designations based on the results of the PACR RI, changes to the MRS designations in the FUDSMIS will be updated by the USACE and used to support scheduling/estimating of future projects, studies, and any cleanup actions determined necessary.

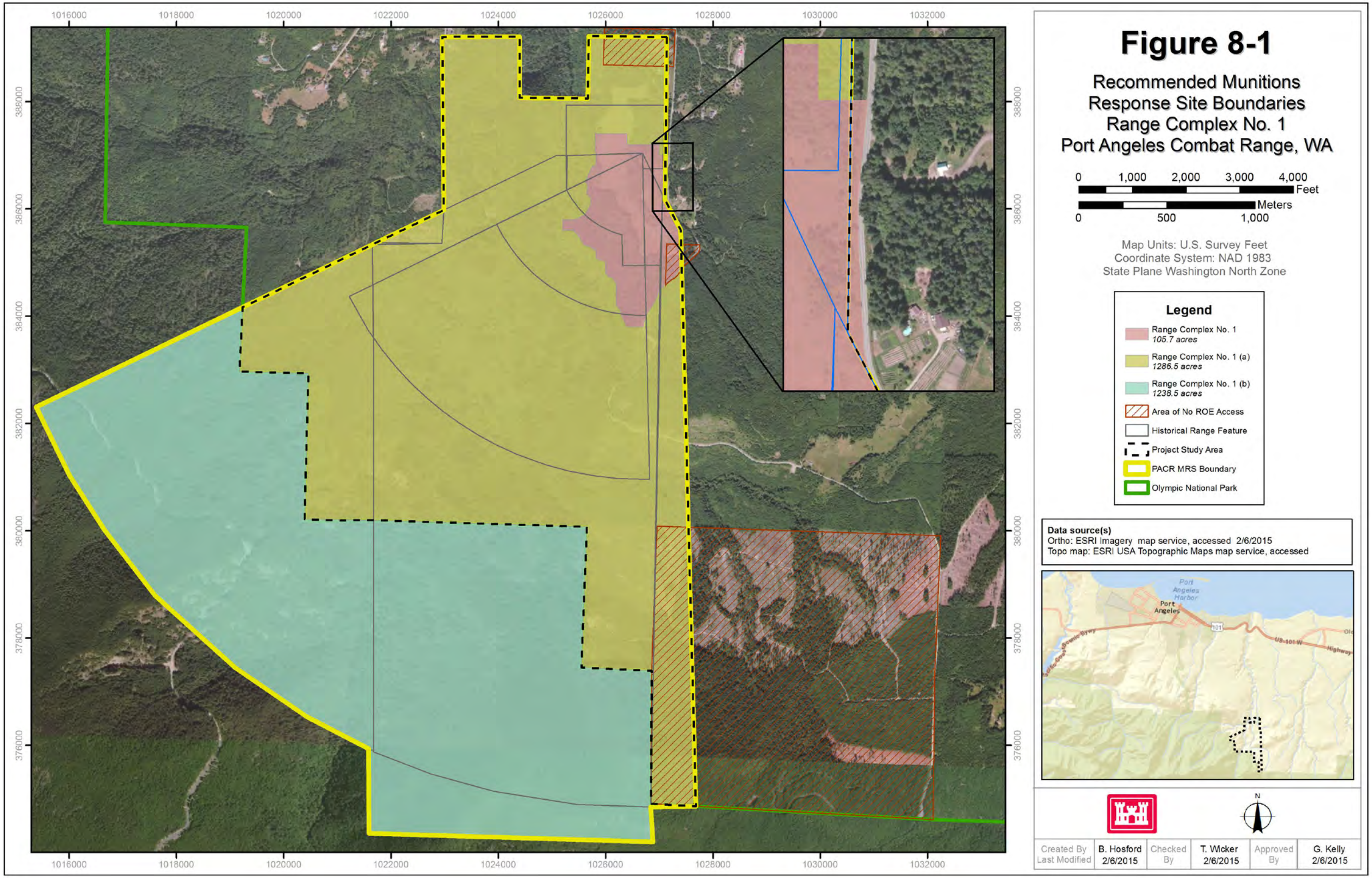
Figure 8-1
Recommended Munitions Response Site Boundaries
Range Complex No. 1
Port Angeles Combat Range, WA
0 1,000 2,000 3,000 4,000 Feet
0 500 1,000 Meters
Map Units: U.S. Survey Feet
Coordinate System: NAD 1983
State Plane Washington North Zone
Legend
Range Complex No. 1 105.7 acres
Range Complex No. 1 (a) 1286.5 acres
Range Complex No. 1 (b) 1238.5 acres
Area of No ROE Access
Historical Range Feature
Project Study Area
PACR MRS Boundary
Olympic National Park
Data source(s)
Ortho: ESRI Imagery map service, accessed 2/6/2015
Topo map: ESRI USA Topographic Maps map service, accessed
Port Angeles Harbor
Port Angeles
101
US-101 W
Highway
N
Created By Last Modified
B. Hosford 2/6/2015
Checked By
T. Wicker 2/6/2015
Approved By
G. Kelly 2/6/2015
1016000
1018000
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9.0 Identification and Screening Technologies for MEC and MC

The remaining sections of this report present the FS conducted for the MRS. As presented in the NCP (40CFR 300.430[e]) (USEPA, 2011), the purpose of the FS is to ensure that remedial alternatives are developed that provide decision-makers with an appropriate range of options and sufficient information to compare alternatives. The following sections describe the alternatives and technologies that may be implemented at the MRS to eliminate or minimize MEC hazard. In this section, RAOs and the process for developing the appropriate alternatives and initial screening are described. The alternatives that may be applicable for the MRS were developed and screened for effectiveness, cost, and implementability as described in **Section 10.0**. Those alternatives determined to be feasible based on these factors were further evaluated and compared in the detailed analysis of alternatives presented in **Section 11.0**. Because there is no evidence of MEC present within the Range Complex 1 (a) and Range Complex 1 (b) these MRSs are not being considered for the establishment of RAOs and the FS.

9.1 Remedial Action Objective

The RAO for the MRS is identified and provides a basis for developing the remedial action alternatives that may be selected to address any possible remaining explosive hazards. Separate alternatives addressing MC were not evaluated because none of the recovered MEC were compromised to the extent that MC was likely released to the environment. It was agreed upon during the SI that MC sampling would not be required. During the SI the stakeholders agreed that if the environmental samples did not exceed regulatory human health screening values additional MC sampling would not be required. The SI did not collect subsurface samples; therefore, the RI still considered the potential for MC to be present in the subsurface. The type and density of MD observed did not indicate that additional MC analysis was required. Therefore, the agreement reached at the end of the SI is still valid. Thus, the RAO focuses on MEC receptors and exposure pathways and drives the development of the munitions response alternatives.

The overall RAO for all of the MRS is to manage the risk of MEC exposure through a combination of removal/remedial actions, administrative controls, and/or public education, thus making the areas as safe as reasonably possible. The RAOs define the measure for success of the adopted remedial action.

The site-specific RAO consider the location, size, and terrain within each area, and specific documentation about the general locations of training exercises, firing points, and other details that might provide information to focus remedial actions. The types of MEC/MD and other evidence of military activity observed were also considered in developing the RAO. The site-specific RAO is:

- For the Range Complex Area No. 1 MRS there is greater potential for MEC to be present within or near the identified impact areas. The RAO for this MRS is to reduce the probability of human interaction with intact MEC on the ground surface, in the subsurface (to a depth of 18 inches bgs based on RI findings), and potentially present in tree trunks. Selection of the PP will be based on the most feasible method that meets the RAO. .

9.2 General Response Actions

General response actions (GRAs) for MEC sites include a NA alternative as required per the NCP to provide a baseline for comparison, LUCs, and applicable clearance alternatives. GRA combinations, such as clearance and LUCs, may be applicable.

Clearance responses may include a combination of surface, subsurface, and timber removal alternatives as appropriate to the site. MEC clearance alternatives may include well-established and innovative detection technologies, as well as recovery and disposal of any MEC items found. Evaluation of innovative technologies is encouraged as described in the CERCLA guidance (USEPA, 1988).

9.3 Identification and Screening of Remedial Technologies

In this step, the potentially applicable technology types and process options are identified and reduced by evaluating the options with respect to technical implementability. The technologies are representative of what is available at the time this FS was prepared. New technologies may become available and will be addressed during the Remedial Design phase. Each GRA and the applicable technologies are identified. Descriptions of the advantages and limitations of each GRA, and a determination about whether they were retained for further evaluation are presented.

9.3.1 Land Use Controls

The LUCs are physical, legal, or administrative mechanisms designed to mitigate risks associated with potential MEC exposure. The selected LUCs must be compatible with current and future land use and must be clearly defined, established in coordination with the landowner or manager, be agreeable to all stakeholders, and they must be enforceable. LUCs are often used in combination with other alternatives to mitigate any hazard remaining following a response action.

The LUC GRA utilizes ICs, and any applicable engineering controls (ECs) implemented at a site to reduce explosive hazards by limiting access and exposure to MEC. ICs are legal controls intended to minimize the potential for human exposure to hazards by limiting land use (e.g. deed restrictions). ECs are physical controls put into place to prevent human and ecological exposure to MEC hazards (e.g. fence). LUCs do not address contamination directly, but rather increase awareness and educate site visitors and workers about the potential hazards, and restrict access to and development of the affected area. In the case of the MRSs, the ICs would include an education component to provide materials and information to site visitors and workers about the possibility of encountering MEC, what to do if a possible MEC item is discovered, and how to report any discoveries.

The LUCs would also include restrictive covenants and deed restrictions in the event the property is transferred from City of Port Angeles control. It should be noted that there is currently a “surface use only” indemnification clause within the property owned by the City of Port Angeles. However, there are also privately (residential and commercial) owned parcels with the MRSs. LUCs might also include use of ECs such as signs and fences to prevent or restrict access.

The advantages of this alternative are:

- Direct exposure through inadvertent site access is reduced.
- The costs are generally lower than other response actions.
- Time to implement the action (i.e., response time) is short.

The limitations of this alternative are:

- There is no MEC removal except in the event of any incidental discoveries or MEC identified during specific projects supported by UXO technicians.
- The City of Port Angeles would be required to ensure that the selected LUCs would be included as deed restrictions if the property is to ever transfer to a new site owner (only applicable to property owned by the City of Port Angeles).
- Deed restrictions on privately owned parcels would be difficult or impossible to implement and enforce.
- Stakeholders must coordinate implementing the selected LUCs for the anticipated life cycle of the site.
- The USACE, as the agency responsible for the FUDS MMRP, must identify mechanisms for funding implementation of all aspects of the LUCs.

Any ICs or ECs selected would need to be implemented and monitored according to an Institutional Control Implementation and Assurance Plan (ICIAP) as described in the IC guidance provided in EPA-540-R-09-002 (USEPA, 2012), and ongoing evaluation of their effectiveness may be addressed through five-year reviews. On-going costs would be incurred for all LUCs until it is determined that no hazard remains. The MRSs are located within municipal and private lands. The City of Port Angeles maintains property within the Range Complex No. 1 MRS as a protected watershed. However, there is no other evidence that the City actively manages the property such as maintenance of fence lines, mowing, etc. The WDNR owns a small portion of land within the MRS that has not been impacted by munitions. Privately owned commercial properties include timber growth and harvesting operations. Privately owned residential properties are generally on the periphery of the PACR MRSs to the north and east.

The LUC GRA was retained for further evaluation as it may be appropriate to meet RAOs for the Range Complex No. 1 MRS or may be incorporated as a component of other alternatives. The LUCs described above are intended to provide a representative technical approach. Specific LUCs will be developed during the Remedial Design phase and within the ICIAP.

9.3.2 Surface Clearance

The surface clearance GRA can range from a simple visual site walkover to a highly controlled series of 100% survey lane inspections depending on the objectives of the surface clearance project. In general, a surface clearance/surface removal is performed to detect, identify, and remove a majority of the MEC and MD on the surface. It is required to be conducted prior to the completion of DGM is support of subsurface MEC detection and removal. Surface clearance is performed by qualified UXO technicians and typically includes use of analog or other geophysical sensors to aid in detecting MEC or MD that may be present.

The advantages of this response action are:

- MEC items found during the clearance activities are removed, thus the MEC hazard is reduced.
- It is relatively low-tech and can be implemented using existing technologies and experience.
- Time to implement is short.

Limitations are:

- Costs, primarily labor costs, associated with 100% or very high coverage rates over a large area may be high, so implementing this alternative can become prohibitively costly.
- Site accessibility due to vegetation and steep terrain may limit the ability to implement full coverage surface clearance.
- Depending on the vegetation cover and procedures for implementing the surface clearance, some vegetation removal could be required.
- Alternative positioning systems or procedures may be required in forested areas where GPS coverage is denied.
- Only MEC at the surface is removed, so subsurface MEC would remain and could be exposed if there is a potential for frost heave, erosion, or mudslides to expose buried MEC.

The surface clearance GRA is technically feasible to be implemented for the Range Complex No. 1 MRS. Therefore, this response action was retained for further evaluation for this MRS. The methodology described above is intended to provide a representative technical approach. Specific procedures will be developed during the Remedial Design phase.

9.3.3 Subsurface Clearance

The subsurface clearance GRA may be achieved through use of one or a combination of geophysical technologies including analog (e.g., Schonstedt magnetometers), DGM (e.g. Geonics EM61 sensor) and advanced classification (e.g., Metal Mapper) techniques. These technologies vary in level of sophistication, cost, ease of use, and availability. Each technology is effective and capable of achieving the RAO as summarized below.

Analog geophysical techniques using sensors such as Schonstedt magnetometers can be used to perform a mag and dig subsurface clearance. These techniques are well known and have historically been used to detect ferrous metal on the surface or in the shallow (< 24 inches) subsurface. This is the type of subsurface investigation that was performed during the RI. The use of analog sensors is the simplest of the geophysical techniques that may be used to locate subsurface anomalies. For this type of subsurface clearance operation, the analog sensors are used to perform a controlled sweep of the area to be cleared, and the locations of any items that register on the sensor are flagged so that a dig team can follow and perform manual excavations to identify and remove MEC or MD items present. Subsurface clearance is performed concurrent with surface clearance activities. A portion of the area that has been cleared, typically 10%, is checked independently by a UXOQCS. A USACE OESS will provide QA. Analog geophysical techniques are completed by UXO qualified personnel as defined by USACE Technical Paper (TP) 18 (DDESB, 2004).

DGM technologies, including industry standard Geonics EM61 sensors, can also be used to perform a subsurface survey to detect subsurface anomalies potentially representing the type of MEC that may be present. These electromagnetic sensors may be deployed on a variety of platforms depending on the site accessibility and terrain, and include towed array, litter, or man-portable platforms. The sensors detect shallow ferrous and non-ferrous metallic objects with high spatial resolution and accuracy and can be conducted to achieve up to 100% coverage of selected areas. These systems are positioned using RTK GPS or equivalent technology to guarantee accurate positioning. Following data processing, analysis, and QC, a dig list is developed to identify anomalies to be reacquired and excavated. The dig locations are marked and manually excavated by a dig team. Subsurface clearance is performed after completion of surface clearance activities. The DGM surveys, anomaly reacquisition, and excavation are performed by qualified geophysicists and UXO Technicians per USACE TP 18. Post-removal verification (PRV) is conducted whereby a percentage, usually 10%, of the area or transects cleared is re-surveyed after the subsurface clearance has been completed to confirm that no subsurface anomalies remain in the cleared areas. The analog geophysical surveys, anomaly reacquisition, excavation, and PRV are performed by qualified UXO and field technicians.

Advanced classification technologies are becoming available that are capable of discriminating anomalies likely to represent MEC, thus providing an ability to significantly reduce the number of anomalies that must be excavated. In large-scale field tests, these technologies have been successfully demonstrated to reduce the number of digs required by up to 90% depending on the munitions types, density, and site conditions. Development and demonstration of advanced EMI sensors deployed on a variety of platforms, along with advanced data processing techniques for discriminating MEC from non-MEC, has resulted in multiple maturing technologies that may be successfully deployed for subsurface clearance activities. These technologies collect a more complex dataset (relative to standard DGM sensors) that can then be processed and analyzed using advanced classification and discrimination algorithms to produce a prioritized dig list that identifies anomalies most likely to represent MEC. These technologies are usually deployed in a cued-interrogation mode (i.e., data are collected while the sensor is stationary) over anomalies previously identified in a standard DGM survey. These technologies have been developed using vehicular and man-portable platforms, so the most appropriate technology can be selected based on site accessibility and terrain. As for DGM, the advanced EMI technologies would be deployed after completion of surface clearance activities. The data collection and processing are performed by qualified geophysicists. UXO technicians perform the excavation of the selected anomalies. PRV is performed following anomaly excavation. As presented in the CERCLA RI/FS guidance (USEPA, 1988), innovative technologies judged to be technically implementable should be retained for further evaluation.

Any areas disturbed by the excavations associated with a subsurface removal would be rehabilitated and re-seeded utilizing native seed mixtures.

The advantages of this GRA are:

- MEC items found during the clearance activities are removed, eliminating or minimizing the potential for exposure and the explosive hazard.
- The technologies can detect MEC items suspected to be present to depths where it is likely to be encountered within the impact and target areas.
- The technologies and data processing and analysis tools are available and generally accepted by stakeholders (additional activities may be required to confirm the performance of the advanced classification technologies).

- These technologies are man-portable, making it feasible to implement this GRA at sites with steep terrain or where access is limited.

Disadvantages are:

- Costs, primarily labor costs, associated with 100% clearance operations over large areas or areas with high anomaly densities are high, so implementing this GRA at sites with these conditions can become very costly.
- Vegetation removal may be required and can be extensive if there are many excavations required.
- Alternative positioning systems or procedures may be required in forested areas where GPS coverage is denied.
- Site accessibility/steep terrain may limit the ability to implement full coverage subsurface clearance.

The subsurface clearance GRA is technically feasible because MEC are likely present in the subsurface, and geophysical techniques are available and effective in performing a subsurface clearance. The subsurface clearance GRA was retained for further evaluation for the Range Complex No.1 MRS. Analog geophysical methods (i.e., use of Schonstedt metal detectors) were selected as a representative subsurface clearance technology for purposes of identification and screening of alternatives and developing the associated costs and level of complexity. The methodologies described above are intended to provide a representative technical approach. Specific procedures will be developed during the Remedial Design phase.

9.3.4 Tree Survey and Clearance

The tree survey and clearance GRA may be achieved through use of one or a combination of GIS technologies, tree stand classification surveys, historical aerial photograph analysis and tree survey and clearance. These techniques vary in level of sophistication, cost, ease of use, and availability. Each technology is effective and capable of achieving the RAOs as summarized below.

A GIS line of sight and slope analysis was conducted during the RI, utilizing publicly available Light Detection and Ranging (LiDAR) data. LiDAR data provides a terrain model that supports highly detailed terrain modeling and represents what terrain that would be visible during munitions training activities from the firing point. The areas identified during the line of sight and slope analysis indicated terrain that may be impacted by artillery, either as a target area or as an area containing munitions that missed the intended target.

Based on the findings of the RI field investigation the Range Complex No. 1 MRS has been delineated as an impact and target area containing MD and likely MEC. In addition to the MD and MEC located on the surface and subsurface, MEC are potentially present in the trunks of the trees that were present at the time the range was operational. It is important to note that the 1948 accident that killed two youths occurred during timber harvesting operations.

A historical aerial photograph analysis was performed to determine what trees were present at the time the range was utilized and subsequently how many acres may contain trees imbedded with MEC. The locations of wooded areas potentially impacted by MEC observed during the RI are generally the same locations when the range was operational; approximately 75 acres have the potential to be impacted by MEC.

In order to address potential MEC hazards in trees the following general process would be required:

- The age of individual trees will be determined.
- Metallic anomalies in the trees would be identified by UXO Technicians.
- Metallic anomalies would be investigated and removed by UXO Technicians.
- Any MEC recovered from the trees would be destroyed.
- Removal and destruction of any trees that could not be certified by UXO Technicians as free of potential MEC hazards would be performed. This includes destruction of MEC that can not be safely removed from the tree trunks.

A professional forester may be employed to assess which trees would have been present within Range Complex No. 1 in the 1940s when the PACR was operational. The forester would estimate the age of the tree by both measuring trunk diameters and utilizing typical growth rates or would collect a boring from the tree and count the number of growth rings. A UXO Technician will be present to identify and avoid interaction with any MEC while the forester conducts the tree surveys.

Once the trees that were present when the PACR was operational are identified, UXO Technicians would utilize metal detectors to locate any metallic anomalies in the tree trunks. This may entail the use of a lift boom to allow the UXO Technicians to look for features that may be indicative of a munitions impact (e.g. tree scarring) and to sweep the tree trunk with a metal detector for anomalies.

If UXO are identified in a tree it is unlikely that the item would be safe to remove due to the sensitive nature of fuzes present within the anticipated munitions and the methods required to remove a UXO item from a tree (e.g. chainsaw). The UXO Technicians would likely utilize shape charges wrapped around the tree trunk to perform a BIP.

The advantages of this GRA are:

- MEC items found during the tree survey and clearance activities are removed, eliminating or minimizing the potential for exposure and the explosive hazard.
- The technologies can detect metallic anomalies present in trees.
- The technologies required to locate metallic anomalies are readily available and inexpensive.

Disadvantages are:

- Costs, primarily labor costs, associated with 100% clearance operations over large areas are high, so implementing this GRA at sites with these conditions can become very costly.
- Vegetation removal may be required and can be extensive.
- Steep terrain and vegetation may limit the ability of the required equipment (e.g. lift boom) to access the site. It is unlikely that all of the trees potentially impacted by MEC could be addressed.
- The use of shape charges on standing timber is extremely hazardous and may present an unacceptable safety risk including the potential to ignite a forest fire.

The tree survey and clearance GRA is technically feasible because MEC may be present in timber, and analog hand held survey techniques are available and effective in assessing the presence of metallic anomalies in timber. The tree survey and clearance GRA was retained for further evaluation for the Range Complex No.1 MRS. The methodology described above is intended to provide a representative technical approach. Specific procedures will be developed during the Remedial Design phase.

9.3.5 Summary of Technology Screening and Evaluation

Table 9-1, on the next page, contains a summary of the screening and evaluation of the representative technologies available at the time that this FS has been prepared.

Table 9-1 Technology Screening and Evaluation

General Response Action	Primary Remedial Technology	Process Options	Screening	Evaluation			
			Technically Implementable?	Effective?	Administratively and Institutionally Implementable?	Cost Prohibitive?	Retained for Consideration*?
No Action	None	None	Yes	N/A	N/A	No cost	Yes
Risk and Hazard Management	Land Use Controls	Access Restrictions (fencing, signage)	Yes	Yes Potentially effective in meeting RAOs	Yes Readily implementable	No Negligible Cost	Yes
		Activity Restrictions (e.g., no intrusive activities allowed)	Yes	Yes. Potentially effective in meeting RAOs	No No oversight enforcement mechanism	No Negligible Cost	No
		Public Education	Yes	Yes Potentially effective in meeting RAOs	Yes Readily implementable	No Negligible Cost	Yes
		Deed Notice	Yes	Yes. Potentially effective in meeting RAOs	No Property is primarily owned by the City of Port Angeles or private owners	No Negligible Cost	No
	MEC Detection	Airborne Geophysical Survey	Yes	No The site vegetation and height of trees would not permit the detection of the smallest munition of concern.	Yes Readily implementable	No High Cost	No
		Geophysical Surveys (digital or analog)	Yes	Yes Potentially effective in meeting RAOs	No Not recommended for high density areas (could be used in outlying areas)	No Moderate Cost	Yes
		Advance Anomaly Classification (e.g., MetalMapper)	Yes	Yes Potentially effective in meeting RAOs	Yes Readily implementable	No High Cost	No
Remedial Action	MEC Recovery	Hand Excavation	Yes	Yes Potentially effective in meeting RAOs	Yes Readily implementable	No Moderate Cost	Yes
		Mechanical Excavation	Yes	Yes Potentially effective in meeting RAOs	Yes Readily implementable	No Moderate Cost	Yes
		Mechanical Excavation and Sifting	Yes	Yes Potentially effective in meeting RAOs	Yes Readily implementable	Yes High Cost	No
	MEC Disposal	MEC Disposal (conducted by qualified UXO personnel)	Yes	Yes Potentially effective in meeting RAOs	Yes Readily implementable	No Moderate Cost	Yes

Notes:
** The technology being retained for consideration is intended to be a representative technology. The alternatives presented in the FS focus on the outcome of the alternative instead of the methodology of a remedial action.*
MEC – Munitions and Explosives of Concern
RAO – Remedial Action Objective
UXO – Unexploded Ordnance

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10.0 Development and Screening of Alternatives

After identifying the GRAs that are technically feasible for the sites considered for remediation, they were evaluated to develop site-specific alternatives and initially screened for effectiveness, cost, and implementability based on the following criteria:

- Effectiveness is evaluated based on the demonstrated ability of the technology to achieve design or remedial action goals and comply with ARARs. Possible adverse effects are also considered.
- Implementability includes factors such as safety, technical feasibility, regulatory and public support, compatibility with current and planned land uses, availability of the technology, site accessibility, and any other issues associated with successful implementation of the alternative. Implementability encompasses both the technical and administrative feasibility of implementing a technology process.
- Costs are evaluated on a relative order-of-magnitude basis and fall within the recommended accuracy range of +50% to -30%, and include costs for implementing the remedial action as well as any post-removal monitoring costs, as appropriate. It is important to include the long-term and life cycle costs so that decision makers are informed about the total costs for each alternative. Cost plays a limited role in the screening of process options. Relative capital, and Operation and Maintenance (O&M) costs are used rather than detailed estimates. At this stage in the process, the cost analysis is made on the basis of engineering judgment, and each alternative is evaluated as to whether costs are high, low, or medium relative to other alternatives in the same technology type.

In this section, alternatives developed from the GRAs identified in **Section 9.0** are described and screened against the effectiveness, cost, and implementability criteria.

10.1 Development of Alternatives

As described in the CERCLA guidance (USEPA, 1988), the GRAs should be evaluated and combined into site-specific alternatives. The alternatives applicable to the MRSs were developed based on the following general criteria:

- The alternative is protective of human health and environment by eliminating, reducing, or otherwise controlling risks or hazards posed by the site.
- There are a reasonable number and type of alternatives based on the characteristics and complexity of the sites, including current site conditions and physical constraints.
- At least one permanent cleanup action alternative must be identified to serve as a baseline against which other alternatives shall be evaluated for the purpose of determining whether the cleanup action selected is permanent to the maximum extent practicable.
- Alternatives may consist of one or more components, including, but not limited to: components that remove MEC from the site; provide for on-site or off-site demolition and disposal of MEC; and, on-site isolation of MEC with ECs and/or ICs.
- The alternative meets the RAOs established for one or more of the MRSs.

The GRAs described in **Section 9.0** were selected individually or in combination to develop remedial action alternatives that apply to the MRSs as follows:

- Alternative 1 – NA
- Alternative 2 – LUCs for Site Visitors and Workers
- Alternative 3 – Surface Clearance and LUCs
- Alternative 4 – Surface Clearance, Subsurface Clearance, and LUCs
- Alternative 5 – Surface Clearance, Subsurface Clearance, Tree Survey and Clearance, and LUCs

The costs developed for the alternatives were based on 2014 rates, and estimated rates for stakeholder costs for the LUC alternatives. Costs applicable for one or more of the alternatives include estimates for:

- Planning documents and meetings.
- Materials (e.g., sign fabrication).
- Equipment rental.
- Mobilization and demobilization of field teams and equipment.
- Labor costs for the remedial action team (e.g. GIS analysts, UXO Technicians, Foresters, etc.).
- Travel (assume field teams would be stationed near Port Angeles for the duration of each field effort).
- Explosives for MEC demolition.
- For the clearance alternatives, multi-year efforts and associated cost escalation were assumed.
- Status reporting.
- GIS hosting.
- Project management and cost controls.

10.2 Screening of Individual Alternatives

A detailed description and the screening analysis for each alternative are presented in the following subsections.

10.2.1 Alternative 1 – No Action

The NA alternative involves taking no current or future action at any of the MRSs.

- Effectiveness: The NA alternative does not reduce or prevent exposure to MEC, and does not provide short or long-term reduction in explosive hazard. Exposure pathways would remain for current and future receptors. This alternative would not address the RAOs.
- Implementability: This alternative is technically and administratively feasible and no services or materials are needed for implementation.
- Cost: The total estimated cost for this alternative is $0. There are no capital or post-remediation costs, contingencies, or professional or technical services associated with this alternative.

This alternative is included in accordance with the NCP and is used to provide a baseline for alternative comparison. As required, it will be retained for detailed analysis for all MRSs.

10.2.2 Alternative 2 – Land Use Controls for Site Visitors and Workers

The LUC alternative for site visitors and workers includes ICs such as preparation and distribution of informational materials for site visitors and workers. Distribution of these materials would be coordinated through the USACE and would include information or notification to local communities and other interested persons. The materials would describe the munitions that may be encountered, what to do, and how and where to report any findings. Development and access to the educational materials would be coordinated through and funded by USACE. The alternative could include ECs such as warning and restricted access signs and fencing to further restrict access. The fencing LUC is limited to the Range Complex 1 MRS due to the presence of MEC and MD identified during the RI. Installation of signs or fences would be performed by the USACE.

The LUC alternative also addresses mitigation of hazards to site workers performing forest and watershed management activities. ICs would include administrative controls prohibiting intrusive activities and timber harvesting without proper notifications and procedures. If the property is transferred at some time in the future, the LUCs would need to be included as restrictive covenants and deed restrictions in the property transfer documents. The components of LUC development and implementation for the MRSs would include:

- Maintaining a dedicated former PACR webpage on the City of Port Angeles website (or other location) with educational material, including photos of munitions that may be encountered and instructions for what to do upon discovery of a munitions item and how to report findings.
- Providing informational materials and the website link at City of Port Angeles offices, and as part of any special use permits, agreements or leases issued by the City of Port Angeles.
- Providing materials to agencies issuing hunting and fishing licenses to distribute to hunters and anglers.
- Providing materials to local libraries and other appropriate public venues.
- Posting signs at strategic access points. Conducting monitoring to ensure signs have not been damaged or removed, and provide resources to replace or install new signs.
- Planning activities to identify the type of use restrictions (such as prohibiting intrusive activities and timber harvesting), responsible parties for conducting long-term IC activities and maintenance of ECs, estimated costs, and funding mechanisms.
- Implementation and monitoring activities for documenting and putting the selected LUCs in place and ensuring their continued effectiveness, including preparation of an ICIAP and updates following five-year reviews.
- Establishing a process to modify or transfer the LUCs in the event the property is transferred from City of Port Angeles or other property owner’s control.
- Installation of approximately 10,500 linear feet of a 6-foot tall chain link fence (limited to the 105.7 acres of the Range Complex No. 1 MRS).

Preparation of the ICIAP would be required upon completion of the PP/DD for the MRSs. The objectives of this document would be to systematically establish and document the activities associated with implementing and ensuring the long-term stewardship of the LUCs, and specify the persons and/or organizations responsible for conducting these activities (USEPA, 2012).

- **Effectiveness**: This alternative provides limited short and long-term reduction of explosive hazard by promoting awareness and providing information to site visitors and workers about potential hazards and how to avoid them. This alternative does not remove or limit exposure pathways. In general, exposure pathways for most of the MRS acreage would remain unchanged for current and future receptors.

- **Implementability**: This alternative is technically feasible, administratively feasible, and services and materials necessary to implement the LUCs are readily available. This alternative is technically feasible because the action is achievable using readily available services and equipment for website development; coordination with local agencies, venues, and vendors to distribute informational material; and sign fabrication and installation.

  An ICIAP would be required upon completion of the PP/DD. Constraints to implementing the LUCs include identifying and establishing long-term funding mechanisms for LUC implementation. The technical and administrative requirements identified to implement this alternative would be included in the ICIAP.

  Constraints to implementing the LUCs include developing a mechanism to ensure long-term funding for developing and maintaining the website, preparing and printing informational materials, monitoring and replacing warning and informational signs and updates to the ICIAP. As the agency responsible for environmental cleanup on former military land under the FUDS program, the USACE would be responsible to fund activities required as part of the LUCs. This alternative is administratively feasible because the technologies and capabilities needed to implement LUCs are available. There are no known permits, waivers, easements, or right-of-way agreements necessary to install signs as the property impacted by munitions is primarily under management of the City of Port Angeles.

  Access to reach some areas where the installation of a fence would be required may be challenging due to the steep terrain and heavy vegetation. However, it is not anticipated that these factors will prevent the installation of the fence restricting access to the areas potentially containing MEC (Range Complex No.1 MRS).

- **Cost**: Costs are shown in Section 11.3.5 (**Table 11-1**) below for implementing the LUCs that would be likely to apply under this alternative. Costs include website development and maintenance, preparing general informational materials (e.g., pamphlets), fabrication of road signs, installation of a fence around the Range Complex No. 1 MRS and the associated project management, planning documents and reports. Costs are based on 2014 rates for these activities and include costs for planning documents, reporting, and administrative costs. Costs for initial preparation and subsequent updates to the ICIAP were estimated assuming costs for several technical planning meetings among stakeholders as well as a document preparation and review cycle. Updated ICIAP updates were assumed to be required following Five-Year reviews. The selection of the alternative during the PP and DD may exclude certain aspects of the LUCs such as the installation of a fence line.

  This alternative is effective in meeting the RAOs technically and administratively, feasible, effective, and implementable, and was retained for detailed analysis for all three MRSs.

10.2.3 Alternative 3 – Surface Clearance and LUCs

A surface clearance would be performed by conducting a 100% coverage non-intrusive visual survey of a designated area. Munitions related items identified during the visual survey including MEC would be removed and disposed of. The presence of any small arms and evidence of military activity would also be documented, but the primary focus would be the MEC and MD removal. Non-munitions related metallic material would be removed if the area is to be cleared for DGM surveys. Any MEC found would be either detonated in place or transported to a designated location for consolidated disposal following established procedures. Surface clearance would be conducted by teams according to the requirements of USACE TP-18 (DDESB, 2004). The UXO technicians would use a magnetometer (e.g., Schonstedt) or other approved geophysical sensor to aid in detecting metal on the ground surface.

Prior to beginning fieldwork, a work plan would be developed and approved as required by stakeholders. An ESS would be developed and approved as required by the USACE. All field activities would be coordinated with the municipal and private landowners to ensure all required permits or licenses would be obtained. Work planning and implementation would be conducted in compliance with Occupational Safety and Health Administration (OSHA) regulations to ensure worker health and safety, ARARs or TBC, regulations for handling and transportation of explosive materials, and destruction of MEC.

The area to be surveyed would first be defined and the boundaries marked using a professional land survey or other pre-approved survey method. Depending on the survey area, some vegetation clearance may be conducted with a small piece of power equipment; such as a walk behind brush hog, if it is determined that the ground surface is completely obscured and cannot otherwise be surveyed. Multiple grids would be developed based on the size and extent of the area to be surveyed, topography, and other factors to ensure that the required coverage would be completed as efficiently as possible. The grids would be divided into search lanes using ropes, pin flags, or other suitable markers. Lane sizing to meet the required coverage would be determined based on the site conditions (for example, flat open areas may allow for wider sweep lanes while dense vegetation or heavily contaminated areas may call for narrower sweep lanes). The teams would then survey each grid lane and mark or flag any items found for further inspection.

If an item is discovered the MPPEH inspection process will be completed in accordance with DODI 4140.62, EM1110-1-4009 and EM385-1-97. If identified as a fuzed MEC item or an item that is unsafe to move, the item would be carefully marked, photographed and its location recorded using a GPS. Then the item would be properly disposed using BIP procedures. Following the BIP, remaining MD would be removed for disposal following established procedures. If the item was determined safe to move, it would be transported to a central location for consolidated disposal with other items. All non-MEC metallic items found would be removed from the surface and consolidated for proper disposal if subsequent DGM activities are planned.

Quality control procedures would include:

- Establishing an exclusion zone for field operations.
- Ensuring that all personnel have required certifications and training.
- Ensuring that all equipment is operating properly.
- Ensuring that all required notifications and permits are in place.

- Ensuring that all activities are properly and fully documented

To ensure instrument functionality (e.g., GA-52Cx Schonstedt, Vallon VMH3, Minelab Explorer), each instrument operator will be required to sweep the analog test strip using the sweep techniques and instrument settings proposed for the project and detect 100% of the items at least once a day. The analog test strip would be established in a designated area and be used to confirm that the instruments are operating as specified and will accurately detect anticipated MEC items under site conditions. Following clearance of each grid, a final QC inspection of a portion of the grid (typically 10%) would be performed by a designated QC specialist to ensure that the clearance was completed.

Following completion of the surface clearance activities, an after action report would be prepared to document all activities as well as MEC recovered and destroyed. Disposal of MD would be completed following required procedures for handling and demilitarization.

Even though the surface clearance would be anticipated to locate and remove any remaining MEC on the ground surface, there is the potential for subsurface items to remain and be exposed due to erosion, frost heave, or mudslides. Therefore, in addition to conducting surface clearance activities, LUCs would be selected and implemented as described for Alternative 2.

- **Effectiveness:** This alternative would identify and remove all surface MEC within the clearance areas, eliminating short-term, and most long-term explosive hazards. It would also remove surface exposure pathways. They would achieve RAOs and comply with applicable regulations as specified in the final ARARs. Surface clearance is a proven method for surface MEC removal and is accepted by stakeholders as an effective remedy. Surface clearance would not remove subsurface MEC, therefore it is possible that subsurface MEC, if present, could be exposed by natural processes (e.g. erosion or frost heave), therefore the long-term explosive hazard would be reduced but not eliminated. Due to the possibility of exposure of subsurface MEC, the areas may be subject to future monitoring or clearance activities based on recommendations from a five-year review or other process. Subsurface MEC may occur at any location, but is considered more likely to occur within the identified impact and target areas.
- **Implementability:** This alternative is considered technically and administratively feasible, and services to perform the clearance activities are readily available. Coordination with the municipal and private land owners would be required to schedule clearance activities, and contractors performing the work would be required to prepare the planning documents, and comply with all licensing and documentation requirements for handling and transporting explosives as required for MEC destruction. Facilities are available to perform the required demilitarization and recycling of MD recovered from the sites. Selected LUCs would be implemented as described in Alternative 2.
- **Cost:** Costs are shown in **Section 11.3.5** (**Table 11-2**) for implementing surface clearance in the Range Complex No. 1 MRS. These costs were developed utilizing an estimated acreage per day for each alternative. Cost estimates include all of the cost elements listed in **Section 11.1**.The materials and MD disposal costs were based on the amount of material observed during the RI. LUCs would be implemented as described in Alternative 2.

Because this alternative would be effective and is technically feasible, it was retained for detailed analysis for the Range Complex No. 1 MRS.

10.2.4 Alternative 4 – Surface Clearance, Subsurface Clearance, and LUCs

This alternative is presented using analog geophysics technologies (i.e., mag and dig) as a representative technology for subsurface detection and clearance. Due to the dense tree canopy at the PACR, GPS positioning accuracy is not adequate to conduct a DGM investigation. Target DGM utilizing reacquisition is not feasible for the MRSs. Analog geophysics was selected as the most effective subsurface clearance remedy for the PACR; however, the selected technologies, associated procedures, and actual costs would be developed as part of the remedial design.

Because the surface and subsurface technologies and procedures are essentially the same, the two clearances would happen concurrently. For Alternative 4, the subsurface clearance would be performed across the Range Complex No. 1 MRS. Although the subsurface clearance would be anticipated to locate all MEC for removal within the clearance areas, it is possible to miss items due to difficulty in accessing an area, site conditions, or other reasons (e.g., unsurveyable areas). Therefore, LUCs would be implemented to ensure that any future site users or visitors are aware of the potential for MEC to be present.

Vegetation removal would be required and implemented as described above in **Section 10.2.3**. Prior to beginning fieldwork, an Explosives Safety Submission (ESS) would be developed and approved as required by the USACE. All field activities would be coordinated with the municipal and private landowners to ensure all required permits or licenses would be obtained. Work planning and implementation would be conducted in compliance with OSHA worker health and safety requirements, and ARARs and TBCs for transportation of explosive materials and destruction of MEC.

The field procedures would be similar to those described above in **Section 10.2.3** except the subsurface MEC and MD would be removed. Based on the RI, the vertical extent of subsurface munitions is expected to be approximately 18 inches bgs.

Following completion of the subsurface clearance activities, a final report would be prepared to document all activities as well as MEC recovered and destroyed. Disposal of MD would be completed following required procedures for handling, demilitarization, and recycling.

- **Effectiveness:** This alternative would identify and remove all surface and subsurface MEC within the clearance areas, eliminating surface and subsurface pathways and short-term and long-term explosive hazards. This alternative would achieve the RAOs and comply with applicable regulations as specified in the final ARARs. Subsurface clearance is a proven method for MEC remediation and is accepted by stakeholders as an effective remedy.
- **Implementability:** This alternative is considered technically and administratively feasible, and services to perform the clearance activities are readily available. Coordination with municipal and private landowners would be required to schedule field activities, and contractors performing the work would be required to prepare the planning documents, and comply with all licensing and documentation requirements for handling and transporting explosives as required for MEC destruction. Facilities are available to perform the required demilitarization of MD recovered from the sites and the disposition of soil impacted by energetic MC.

- **Cost:** Costs shown in **Section 11.3.5** (**Table 11-3**) were developed utilizing an estimated acreage per day for each alternative. Cost estimates include all of the cost elements listed in **Section 11.1**. LUCs would be implemented as described in Alternative 2.

10.2.5 Alternative 5 – Surface Clearance, Subsurface Clearance, Tree Survey and Clearance, and LUCs

For Alternative 5, in order to address MEC hazards in trees, a tree survey and removal would be performed after completion of the clearances described in Alternative 4.

A GIS line of sight and slope analysis was conducted during the RI, utilizing publicly available LiDAR data. LiDAR data provides a terrain model that supports highly detailed terrain modeling and represents what terrain would be visible during munitions training activities from the firing point. The areas identified during the line of sight and slope analysis indicated terrain that may be impacted by artillery, either as a target area or as an area containing munitions that missed the intended target.

Based on the findings of the RI field investigation the Range Complex No. 1 MRS has been delineated as an impact and target area containing MD and likely MEC. In addition to the MD and MEC located on the surface and subsurface, MEC are potentially present in the trunks of the trees that were present at the time the range was operational. It is important to note that the 1948 accident that killed two youths occurred during timber harvesting operations.

A historical aerial photograph analysis was performed to determine what trees were present at the time the range was utilized and subsequently how many acres may contain trees imbedded with MEC. The locations of wooded areas potentially impacted by MEC observed during the RI are generally the same locations when the range was operational; approximately 75 acres have the potential to be impacted by MEC.

In order to address potential MEC hazards in trees the following general process would be required:

- The age of individual trees would be determined.
- Metallic anomalies in the trees would be identified by UXO Technicians.
- Metallic anomalies would be investigated and removed by UXO Technicians.
- Any MEC recovered from the trees would be destroyed.
- Removal and destruction of any trees that could not be certified by UXO Technicians as free of potential MEC hazards would be performed. This includes destruction of MEC that can not be safely removed from the tree trunks.

A professional forester may be employed to assess which trees would have been present within Range Complex No. 1 in the 1940s when the PACR was operational. The forester would estimate the age of the tree by both measuring trunk diameters and utilizing typical growth rates or collecting a boring from the tree and count the number of growth rings. A UXO Technician will be present to identify and avoid interaction with any MEC while the forester conducts the tree surveys.

Once the trees that were present when the PACR was operational are identified, UXO Technicians would utilize metal detectors to locate any metallic anomalies in the tree trunks. This may entail the use of a lift boom to allow the UXO Technicians to look for features that may be indicative of a munitions impact (e.g. tree scarring) and sweep the tree trunk with a metal detector for anomalies.

If UXO are identified in a tree it is unlikely that the item would be safe to remove due to the sensitive nature of fuzes present within the anticipated munitions and the methods required to remove a UXO item from a tree (e.g. chainsaw). The UXO Technicians would likely utilize shape charges wrapped around the tree trunk to perform a BIP.

Following completion of the tree survey and removal activities, a final report would be prepared to document all activities as well as MEC recovered and destroyed. Disposal of MD would be completed following required procedures for handling, demilitarization, and recycling.

- **Effectiveness:** This alternative would identify and remove all surface and subsurface MEC as well as MEC remaining within trees present when the range was operational, eliminating all exposure pathways and the short-term and long-term explosive hazards. This alternative would achieve the RAOs and comply with applicable regulations as specified in the final ARARs. Subsurface clearance is a proven method for MEC remediation and is accepted by stakeholders as an effective remedy.
- **Implementability:** This alternative is considered technically and administratively feasible, and services to perform the clearance activities are readily available. Coordination with municipal and private landowners would be required to schedule field activities, and contractors performing the work would be required to prepare the planning documents, and comply with all licensing and documentation requirements for handling and transporting explosives as required for MEC destruction. Facilities are available to perform the required demilitarization of MD recovered from the sites and the disposition of soil impacted by energetic MC. The tree survey and clearance is considered less feasible compared to the other alternatives presented within this FS because of access limitations due to the thick vegetation and steep terrain. The removal of MEC within trees may also pose a greater risk than any MEC remaining in-situ.
- **Cost:** Costs shown in **Section 11.3.5** (**Table 11-4**) were developed utilizing an estimated acreage per day for each alternative. Cost estimates include all of the cost elements listed in **Section 11.2.4**. Surface and subsurface clearance costs also would be incurred and are shown separately. LUCs would be implemented as described in Alternative 2.

10.2.6 Range of Appropriate Alternatives

Alternative 1, the no action alternative is applicable to all MRSs. The other alternatives are applicable to the areas where there is a remaining hazard associated with munitions, specifically the Range Complex No. 1 MRS. Since the Range Complex No. 1 MRS is the only area identified to contain a hazard associated with munitions it is the only MRS retained for evaluation. Due to the lack of evidence of MEC in the Range Complex No. 1 (a) MRS and the Range Complex No. 1 (b) MRS these MRSs are no longer being retained for the detailed analysis of alternatives. **Table 10-1** presents a summary of the screening and range of appropriate alternatives for the Range Complex No. 1 MRS.

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Table 10-1 Screening Individual Remedial Alternatives, Range Complex No. 1 MRS

No.	Alternative	Major Components	Screening Criteria			Retained?
			Effective?	***Implementable?***	***Cost Prohibitive?***	
1	No Action Alternative	• Required by NCP for comparison purposes only • No MEC clearance would be conducted • No LUCs would be implemented	No Does not provide any protection from the MEC hazards associated with the MRS.	Yes	No No Cost	Yes
2	Land Use Controls	• Maintaining a dedicated former PACR webpage on the City of Port Angeles website (or other location) • Providing informational materials and website link at City of Port Angeles offices • Providing materials to agencies issuing hunting and fishing licenses to distribute to hunters and anglers • Providing materials to local libraries and other appropriate public venues • Posting signs at strategic access points • Establishing a process to modify or transfer the LUCs in the event the property is transferred from City of Port Angeles or other property owners control • Installation of approximately 10,500 linear feet of a six-foot tall chain link fence (limited to the 105.7 acres of the Range Complex No. 1 MRS) • Five-year reviews would be conducted	Yes Fencing reduces receptor exposure to MEC hazards. Reduces risk by providing information to land owners and public. Fact sheets and website will provide hazard recognition to reduce chance of exposure.	Yes Methods for this alternative are all proven, well-established, and administratively feasible.	No Low Cost	Yes
3	Surface Clearance and LUCs	• LUCs as described above in item 2 • 100% coverage non-intrusive removal action of MEC located on the ground surface • Five-year reviews would be conducted	Yes Somewhat effective in meeting RAOs since MEC on the surface would be removed.	Yes Methods for this alternative are all proven, well-established, and administratively feasible.	No Moderate Cost	Yes
4	Surface Clearance, Subsurface Clearance, and LUCs	• LUCs as described above in item 2 • 100% coverage non-intrusive removal action of MEC located on the ground surface • MEC clearance to a fixed depth of 18 inches bgs • Five-year reviews would be conducted	Yes Effective in meeting RAOs; however, the potential for MEC within tree trunks would still exist.	Yes Remedial action methods for this alternative are all proven, well-established, and administratively feasible; skilled labor readily available from MEC clearance.	Yes Moderate to High Cost	Yes
5	Surface Clearance, Subsurface Clearance, Tree Survey and Clearance, and LUCs	• LUCs as described above in item 2 • 100% coverage non-intrusive removal action of MEC located on the ground surface • MEC clearance to a fixed depth of 18 inches bgs • A tree survey would be conducted to identify what trees would have been present during the period when the range was operational • MEC would be removed from the trees • Five-year reviews would be conducted	Yes Fully effective in meeting RAOs and is the UU/UE alternative.	Yes Remedial action methods for this alternative are all proven, well-established, and administratively feasible; skilled labor readily available from MEC clearance.	Yes High Cost	Yes

Notes:
bgs – below ground surface
LUC – Land Use Control
MEC – Munitions and Explosives of Concern
MRS – Munitions Response Site
NCP – National Oil and Hazardous Substances Pollution Contingency Plan
PACR – Port Angeles Combat Range
RAO – Remedial Action Objective
UU/UE - Unrestricted Use/Unrestricted Exposure

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11.0 Detailed Analysis of Alternatives

11.1 Introduction

The detailed analysis of alternatives relative to the CERCLA criteria is presented in this section. Comparative analysis of the alternatives and a table summarizing the results and scoring for each alternative is also presented.

The purpose of the detailed analysis of alternatives is to evaluate and compare the alternatives remaining after the initial screening. Section 300.430(e) (9) (iii) of the NCP describes the nine criteria for evaluating and comparing alternatives. During the detailed analysis, the alternatives are individually evaluated and then compared to one another with regard to their relative performance against each of the criteria. The nine criteria are described below.

The first two criteria are **Threshold Criteria**, or requirements each alternative must meet or have specifically waived to be eligible for selection.

1. Criterion for Protectiveness of Human Health and the Environment – The overall protectiveness of an alternative is a combination of the magnitude of the residual risk/hazard following the action and the short-and long-term effectiveness of the alternative. The MEC HA results are used qualitatively to evaluate the relative protection associated with the alternatives.
2. Compliance with ARARs and TBCs – Evaluation of this criterion is based on the statutory laws and regulations and any other identified state or federal guidance or policies as applicable to the site and alternatives. The alternatives are evaluated with regard to their ability to comply with ARARs and TBCs.

The next five criteria are **Balancing Criteria**, and form the basis for performance comparison among alternatives that meet the Threshold Criteria.

3. Permanence and long-term effectiveness – this criterion evaluates the degree to which the alternative permanently reduces or eliminates the explosive hazard for MEC, the magnitude of residual risk/hazard with the alternative in place, and the effectiveness of controls to manage the residual risk/hazard. Non-clearance alternatives (NA and LUCs) have negligible impact in reducing MEC sources and explosive exposure hazards since no MEC will be removed as a direct consequence of implementing these alternatives.
4. Reduction of toxicity, mobility, or volume through treatment – This is a balancing criterion that assesses the degree to which the alternatives employ recycling or treatment reducing toxicity, mobility, or volume. For MEC, the toxicity and volume are not directly relevant. Therefore, the volume reduction or removal of MEC is the primary factor used to evaluate a MEC alternative. As previously noted, there were no unacceptable risks to human health or the environment for MC, therefore the alternatives evaluation is focused to the reduction of the hazards associated with MEC.
5. Short-term effectiveness – this criterion addresses the potential consequences and effects of an alternative during the implementation phase. Short-term risks address adverse impacts to the workers, community, and the environment during the implementation phase of the action.
6. Implementability – This criterion can include technology and administrative requirements. Technical requirements may include access due to terrain, vegetation, soils, water, or hazards; availability of technology and equipment; ability to determine effectiveness; and the ability to

integrate munitions responses with other environmental actions. Administrative requirements may include the ability to implement and enforce deed restrictions, covenants, etc.
7. Cost – Cost is a balancing criterion used to evaluate the capital cost, annual Operations and Maintenance (O&M) cost, and net present value cost associated with each alternative. Cost estimates developed at this stage should have a desired accuracy of -30% to +50%.

The last two criteria are **Modifying Criteria** considered in remedy selection, and are typically not formally evaluated at the FS stage. Therefore, they are not addressed in the comparative assessments of alternatives in the following sections of this FS.

8. Regulatory Acceptance – this criterion cannot be fully evaluated at this stage and will be evaluated following comment on the RI report, FS and the proposed plan regarding the regulators' preferences or concerns about the alternatives, and prior to remedy selection.
9. Community Acceptance – this criterion cannot be fully evaluated at this stage and is generally the last stage of the process prior to remedy selection, and is evaluated when the PP has been issued and the public meeting and comment period has been conducted so that community members' preferences or concerns have been provided. Community acceptance can be estimated based on community outreach efforts.

For the alternatives analysis, the Threshold and Balancing criteria were analyzed and a relative score from zero to 10 was assigned for each alternative and criterion. A value of zero represents the poorest performance while a value of 10 represents the best performance. The results are compiled in tables following the comparative analysis discussion for all of the alternatives. Due to the lack of evidence of MEC in the Range Complex No. 1 (a) MRS and the Range Complex No. 1 (b) MRS these MRSs were not retained for the detailed analysis of alternatives.

11.2 Individual Analysis of Alternatives

11.2.1 Alternative 1 – No Action

The NA alternative is included as a baseline for comparison against all other alternatives. For this alternative, no action would be taken at any of the MRSs.

11.2.1.1 ALTERNATIVE – NA DESCRIPTION

The NA alternative does not reduce MEC hazard and therefore does not meet the threshold criterion for protectiveness or the balancing criteria for long-term effectiveness or reduction of volume of MEC as no MEC would be removed and all exposure pathways would remain intact. This alternative represents the MEC HA baseline condition. The MEC HA baseline hazard levels is 2 for the Range Complex No. 1 MRS. As no direct action would be taken, there is no short-term effect upon workers or site visitors. No costs or implementation limitations are associated with this alternative. It is carried through the FS as specified in the NCP. The NA alternative scores were assigned as follows:

1. Protectiveness – 0
2. ARARs compliance – Not Applicable (N/A)
3. Permanence and long-term effectiveness – 0
4. Reduction in mobility, toxicity, or volume – 0
5. Short-term effectiveness – 10
6. Implementability – 10
7. Cost – 10

11.2.2 Alternative 2 – Land Use Controls for Site Visitors and Workers

11.2.2.1 ALTERNATIVE 2 – DESCRIPTION

Alternative 2, LUCs for Site Visitors and Workers, includes ECs such as warning and restricted access informational signs and fencing to further restrict access. ICs include administrative controls prohibiting intrusive activities and timber harvesting without proper notifications and procedures. If the property is transferred at some time in the future, the LUCs would need to be included as restrictive covenants and deed restrictions in the property transfer documents. In addition, ICs include development and maintenance of a website to provide information, and coordination with local agencies, public venues, and vendors to distribute site visitor information. This might include agencies issuing hunting and fishing permits and local libraries. The LUCs that apply specifically to site workers would include developing and distributing training and educational materials and programs for workers performing road maintenance or construction or forest and watershed management projects that could result in more extensive intrusive activities. Preparation of an ICIAP will be required, along with provision for preparing periodic updates, possibly following five-year reviews.

This alternative is also included as components of the surface, subsurface and tree survey and clearance alternatives and is retained for the Range Complex No. 1 MRS.

11.2.2.2 ALTERNATIVE 2 – ASSESSMENT

The LUC alternative does not meet the Threshold Criterion for hazard reduction, and has permanence or long-term effectiveness in that it provides for increasing receptor awareness but it would not reduce the volume of MEC as no MEC would be removed and all exposure pathways would remain intact. The MEC HA hazard levels are not reduced and are the same as for the baseline condition because no MEC would be removed under this alternative. The MEC HA baseline hazard level is 2 for the Range Complex No. 1 MRS. However, implementing the LUCs promotes increased awareness and provides at least a low level of protectiveness.

As no direct action would be taken, there is no short-term effect upon workers, site visitors, or the environment. This alternative can be quickly implemented. Costs are low relative to the clearance alternatives.

Based on the screening evaluation, this alternative was retained for the Range Complex No. 1 MRS and LUCs were combined with other response actions for Alternatives 3-5. Scoring for LUCs was assigned as follows:

1. Protectiveness – 3
2. ARARs compliance – N/A
3. Permanence and long-term effectiveness – 4
4. Reduction in mobility, toxicity, or volume – 0
5. Short-term effectiveness – 10
6. Implementability – 7
7. Cost – 9

11.2.3 Alternative 3 – Surface Clearance and LUCs

11.2.3.1 ALTERNATIVE 3 – DESCRIPTION

This alternative includes a surface clearance and LUCs. Surface clearance consists of up to 100% visual survey coverage to locate, identify, and remove any MEC found on the surface. Any MEC found would be disposed using BIP procedures if it was unsafe to move, or moved to a central location for consolidated disposal. All field activities would be coordinated with the WDOE to ensure compliance with ARARs related to wildlife protection and management, and all required permits or licenses would be obtained. The surface clearance would be performed by qualified individuals and all MEC identification and disposal activities would be performed by UXO technicians. Prior to and following the surface clearance, LUCs would be implemented, including installing warning signs, developing and distributing educational materials and installation of a fence to restrict access to areas containing MEC and MD. Alternative 3 was retained for the Range Complex No. 1 MRS.

11.2.3.2 ALTERNATIVE 3 – ASSESSMENT

This alternative meets the Threshold Criteria for protectiveness and compliance with ARARs. The MEC HA score for this alternative shows reduced hazard relative to the baseline condition and LUCs alone. For the surface clearance alternative, the MEC HA hazard level is 2 for the Range Complex No.1 MRS.

Surface clearance provides long-term effectiveness and reduction in volume of MEC in that surface MEC would be removed, but the potential for future exposure of buried MEC would remain. There is some risk to site workers performing surface clearance activities both due to possible challenging site conditions related to working in varied and steep terrain, and potential for exposure to MEC. There are extensive areas with thick vegetation and downed trees where the ground surface is obscured. Vegetation clearance may be conducted with a small piece of power equipment; such as a walk behind brush hog. For MEC disposal activities, notifications and exclusion zones would be established as specified in the ESS developed for the site, but these exclusions would be limited to the short timeframe required to set up and complete the disposal activities. If MEC is consolidated to a central location prior to disposal, appropriate exclusion, and limits to access would be employed to ensure protection of all site workers and visitors, but would be limited in extent and duration. Based on these considerations, short-term effectiveness is moderate.

Alternative 3 can be implemented in the Range Complex No. 1 MRS, with the exception of the unsurveyable terrain. However, there may be some limitations to performing 100% surface clearance due to terrain and access limitations, therefore implementability is scored as moderate. Costs are considered moderate relative to LUCs and subsurface clearance. LUC costs for this alternative are assumed to be equivalent to Alternative 2.

Based on this assessment, scoring was assigned as follows for Alternative 3:

1. Protectiveness – 6
2. ARARs compliance – 10
3. Permanence and long-term effectiveness – 6
4. Reduction in mobility, toxicity, or volume – 8
5. Short-term effectiveness – 7
6. Implementability – 7
7. Cost – 7

11.2.4 Alternative 4 – Surface Clearance, Subsurface Clearance, and LUCs

11.2.4.1 ALTERNATIVE 4 – DESCRIPTION

This alternative includes a surface and subsurface clearance using analog geophysics (i.e., mag and dig with Schonstedt magnetometers). Analog geophysics was selected as a representative subsurface technology. For this alternative the surface clearance and subsurface clearance would happen concurrently. All surface and subsurface MD and MEC found within the clearance areas will be removed. If there is vegetation that prevents the deployment of the analog sensors, some vegetation removal may be required. The subsurface investigation performed during the RI indicated that the extent of MD within the impact areas is shallow and nearly all items were found within 18 inches of the surface. The analog geophysical sensors are capable of detecting the suspected MEC items to these depths so clearance to detected depth is readily achievable. Any MEC found during surface and subsurface clearance activities would be disposed of using Blow-in-Place (BIP) procedures if it was unsafe to move, or moved to a central location for consolidated disposal. All field activities would be coordinated with the WDOE to ensure compliance with ARARs related to wildlife protection and management, and all required permits or licenses would be obtained. The surface and subsurface clearance activities would be performed by qualified individuals and all MEC identification and disposal activities would be performed by UXO technicians. Because there would be limited potential for MEC to remain, LUCs would be implemented following the clearance activities.

This alternative was retained for the Range Complex No. 1 because this MRS has the potential for subsurface MEC.

11.2.4.2 ALTERNATIVE 4 – ASSESSMENT

This alternative meets the Threshold Criteria for protectiveness and compliance with ARARs. The MEC HA score for this alternative shows reduced hazard relative to the baseline condition, LUCs, and the surface clearance and LUCs described in Alternatives 1, 2 and 3. For the subsurface clearance alternative, the MEC HA hazard level is 2 for the Range Complex No. 1 MRS. Subsurface clearance provides long-term effectiveness and reduction in volume of MEC in that all surface and subsurface MEC would be removed within the clearance areas. Based on the RI, the vertical extent of subsurface munitions is expected to be approximately 18 inches bgs. There is some risk to site workers performing surface and subsurface clearance activities due to both possible challenging site conditions and terrain, and potential for exposure to MEC. There could be environmental impacts due to the disturbance caused by the surface clearance and excavations. Complete vegetation removal would not be anticipated for the clearance activities. For MEC disposal activities, notifications and exclusion zones would be established as specified in the ESS developed for the site, but these exclusions would be limited to the short timeframe required to set up and complete the disposal activities. If MEC will be consolidated to a central location prior to disposal, appropriate exclusion, and limits to access would be employed to ensure protection of all site workers and visitors, but would be limited in extent and duration. Based on these considerations, short-term effectiveness is scored as moderate.

Alternative 4 would be performed within the one MRS (Range Complex No. 1) that contains impact and target areas. This area should be mostly accessible for deploying analog geophysical sensors (e.g. Schonstedt magnetometers); therefore, implementability is scored as moderate. The unsurveyable areas would not be included in any clearance activities. Costs are considered high relative to the LUC and surface clearance alternatives because all identified MEC/MD in the surface and subsurface would be located and removed. Costs for this alternative are higher with respect to alternatives 1 through 3 because of the higher cost to excavate the subsurface anomalies.

Based on this assessment, scoring was assigned as follows:

1. Protectiveness – 9
2. ARARs compliance – 10
3. Permanence and long-term effectiveness – 9
4. Reduction in mobility, toxicity, or volume – 9
5. Short-term effectiveness – 6
6. Implementability – 6
7. Cost – 5

11.2.5 Alternative 5 – Surface Clearance, Subsurface Clearance, Tree Survey and Clearance, and LUCs

11.2.5.1 ALTERNATIVE 5 – DESCRIPTION

This alternative includes surface and subsurface clearance using analog geophysics and then removal of any trees that were believed to be present in the late 1940s when the Range Complex No. 1 MRS was operational. The surface and subsurface clearance would be performed as described above in Alternative 4. For this alternative, a professional consulting forester would be employed to assist in determining the age of the trees. Trees that are considered to be of the optimum age would be evaluated by UXO Technicians. Any metallic anomalies identified by the UXO technicians would be addressed by either inspection or disposal to certify the tree as free from explosive hazards.

This alternative was retained for the Range Complex No. 1 because this MRS has the potential for the presence of MEC.

11.2.5.2 ALTERNATIVE 5 – ASSESSMENT

This alternative meets the Threshold Criteria for protectiveness and compliance with ARARs. The MEC HA score for this alternative shows reduced hazard relative to the baseline condition, LUCs, surface clearance, and subsurface clearance described in Alternatives 1 through 4. For this alternative, the MEC HA hazard levels is 3 for the Range Complex No. 1 MRS. Surface and subsurface clearances and tree survey clearances provide long-term effectiveness and a reduction in volume of MEC because all detected MEC present within the Range Complex No. 1 MRS would be removed. There is some risk to site workers performing clearance activities due to both possible challenging site conditions and terrain, and potential for exposure to MEC. There could be environmental impacts due to the disturbance caused by the subsurface clearances and tree survey and clearance. Complete vegetation removal would not be anticipated for the clearance activities. For MEC disposal activities, notifications and exclusion zones would be established as specified in the ESS developed for the site, but these exclusions would be limited to the short timeframe required to set up and complete the disposal activities. If MEC will be consolidated to a central location prior to disposal, appropriate exclusion, and limits to access would be employed to ensure protection of all site workers and visitors, but would be limited in extent and duration. Based on these considerations, short-term effectiveness is scored as moderate. This alternative would be performed within identified impact areas.

Alternative 5 would be performed within the one MRS (Range Complex No. 1) that contains impact areas. This area should be mostly accessible for deploying teams to perform the surface and subsurface clearances and the tree surveys and removal. It is anticipated that there will be some trees that won't be accessible by the required equipment to evaluate metallic anomalies in trees; therefore, implementability is scored as moderate. The unsurveyable areas would not be included in any clearance activities. Costs are considered high relative to the four other alternatives because all identified MEC/MD would be located and removed. Costs for this alternative is the highest among all of the alternatives evaluated because of the higher cost to deploy the foresters, timber harvesters, UXO technicians, wildlife biologists, and community fire safety professionals, and removal of all anomalies that have signals would be required.

Based on this assessment, scoring was assigned as follows:

1. Protectiveness – 10
2. ARARs compliance – 10
3. Permanence and long-term effectiveness – 9
4. Reduction in mobility, toxicity, or volume – 10
5. Short-term effectiveness – 5
6. Implementability – 3
7. Cost – 2

11.3 Comparative Analysis of Alternatives

For the comparative analysis, the ranks for each alternative were compiled and summed to support evaluation of the performance and effectiveness of the applicable alternatives for the Range Complex No. 1 MRS. The following comparative analysis presents a narrative discussion describing the strengths and weaknesses of the alternatives relative to one another with respect to each criterion, and how reasonable variations of key uncertainties could change the expectations of their relative performance.

11.3.1 Protectiveness and ARARs Compliance

The protectiveness criterion evaluation provides a check to assess whether each alternative provides adequate protection of human health and the environment. The overall assessment incorporates the assessments for long-term effectiveness and permanence, and short-term effectiveness. Compliance with ARARs and TBCs is a requirement for any alternative to be considered feasible, with the exception of the baseline NA alternative.

The protectiveness criterion evaluation provides a check to assess whether each alternative provides adequate protection of human health and the environment. The overall assessment incorporates the assessments for long-term effectiveness and permanence, and short-term effectiveness. Compliance with ARARs and TBCs is a requirement for any alternative to be considered feasible, with the exception of the baseline NA alternative.

Alternative 1, NA is included per the NCP to provide a baseline against which all other alternatives can be compared. It does not meet the protectiveness criterion as no reduction in MEC hazard would be achieved and it therefore has no long-term effectiveness with regard to removing MEC or exposure pathways. As no action would be taken, ARARs compliance and short-term effectiveness criteria do not apply.

Alternative 2, LUCs for Site Visitors and Site Workers, provides a moderate level of protectiveness by restricting access and preventing intrusive activities. Fencing may be installed to further restrict access if trespassing is a concern. The LUCs would be transferred to new landowners if property within the MRS impacted by munitions is ever transferred. Alternative 2 also provides limited protectiveness and possible reduction in exposure to MEC hazards through education and training.

Alternative 3, Surface Clearance and LUCs, provides a moderate level of protectiveness within the clearance areas. For Alternative 3, the Range Complex No. 1 MRS would be cleared and would achieve a moderate level of protectiveness, especially if 100% coverage is achieved. Completion of a surface clearance should remove all MEC located on the ground surface and remove surface exposure pathways. Long-term effectiveness of this alternative is considered to be moderate for impact areas in that subsurface MEC would remain and could be exposed through frost heave or erosion, or it could be transported and exposed by mudslides. There is a much lower probability for subsurface MEC outside the impact areas so the long-term effectiveness for this alternative is considered high in the clearance areas. Because of the potential for subsurface MEC, it is possible that additional monitoring or removal activities may be recommended in a Five-Year Review after implementation of a surface clearance remedy. LUCs also would be implemented to mitigate any remaining hazard by promoting awareness of the potential hazard to all site users and providing training for any site workers (e.g. wildlife biologists or utility workers). Short-term effectiveness is moderate since there would be some MEC exposure hazard associated with clearance activities. However, the requirement to have the clearance activities led by qualified UXO technicians and to have appropriate ESS and health and safety plans in place mitigate the hazard and safety risks as much as possible.

All activities associated with this alternative would comply with ARARs. In particular, coordinating field activities regarding wildlife or habitat disturbance with the WDOE would be conducted, and requirements for compliance with OSHA standards, explosives transport and handling, and MEC disposal procedures would be met.

Alternative 4, Surface Clearance, Subsurface Clearance, and LUCs, provides a high level of protectiveness by removing both surface and subsurface MEC. Subsurface clearance alternatives are considered feasible only for the Range Complex No. 1 MRS because of the likelihood of the presence of subsurface MEC.

With this alternative, it is possible that some MEC would be missed and exposure pathways and MEC hazard cannot be assumed to be completely eliminated; therefore, LUCs would be implemented. All activities for these alternatives would comply with ARARs. In particular, coordinating field activities regarding wildlife or habitat disturbance with the WDOE would be conducted, and requirements for compliance with OSHA standards, explosives transport and handling, and MEC disposal procedures would be met.

Alternative 5, Surface Clearance, Subsurface Clearance, Tree Survey and Clearance, and LUCs, provides the highest level of protectiveness by removing both surface and subsurface MEC, as well as MEC imbedded in trees. This alternative is considered feasible only for the Range Complex No. 1 MRS because of the likelihood of the presence of subsurface MEC and MEC in trees.

With this alternative, it is possible that some MEC would be missed and exposure pathways and MEC hazards cannot be assumed to be completely eliminated; therefore, LUCs would be implemented. All activities for this alternative would comply with ARARs. In particular, coordinating field activities regarding wildlife or habitat disturbance with the WDOE would be conducted, and requirements for compliance with OSHA standards, explosives transport and handling, and MEC disposal procedures would be met.

11.3.2 Long-Term Effectiveness and Permanence

This criterion addresses the results of a remedial action in terms of the risk remaining at the site after response objectives have been met. For the three MRSs, rather than evaluating the remaining risk, the remaining explosive hazard posed by MEC is addressed since MC was not reported at levels that could pose a risk to human or ecological receptors. This criterion is evaluated in terms of the magnitude of residual hazard, adequacy of the response action in limiting the hazard, and the required LUCs and any long-term monitoring that may be required.

Alternative 1, NA, represents the baseline conditions for comparison with the other alternatives. The NA alternative provides no hazard reduction and does not reduce or eliminate any exposure pathways.

Alternative 2, LUCs for Site Visitors and Site Workers, provides hazard reduction in that access to the MRSs would be restricted and administrative controls prohibiting intrusive activities would be documented. Exposure pathways would be not be eliminated but would be reduced through limiting access. Development of supplemental informational and educational materials alone would not provide direct hazard reduction.

The MEC HA results indicate no reduction in the hazard level for any of the MRSs for this alternative. However, this alternative is still considered feasible and as a component of Alternatives 3, 4, 5. This alternative is considered applicable for all three MRSs either alone or as a component of the clearance alternatives.

Alternative 3, Surface Clearance and LUCs provide the next greatest reduction in explosive hazard since MEC present on the surface would be found and removed within the clearance areas, thus removing the surface exposure pathway for at least the short term. Surface clearance may not offer a long-term or permanent solution in areas where there is moderate or high probability of subsurface MEC because the subsurface MEC could be exposed through frost heave, erosion, or mudslides. For this reason, the MEC HA Hazard Level Category is reduced by one level for the MRSs where surface clearance is considered implementable. LUCs would be required following implementation of surface clearance to promote and maintain user awareness and provide training for site workers.

Alternative 4, Surface Clearance, Subsurface Clearance, and LUCs, provides the next greatest reduction in explosive hazard. Alternative 4 was retained only for the Range Complex No. 1 MRS because of the potential for subsurface MEC to be present. Subsurface clearance was not retained for the Range Complex No. 1 (a) MRS or the Range Complex No. 1 (b) MRS because of the lack of evidence of a target or impact area. Based on the MEC HA results, subsurface clearance reduces the hazard ranking from the high potential hazard conditions (Hazard Level 2) to moderate potential hazard conditions (Hazard Level 3) for the Range Complex No. 1 MRS. The subsurface exposure pathway would be minimized or possibly eliminated altogether in the areas that undergo subsurface clearance.

Under this alternative, all anomalies with signals that exceed a specified threshold are excavated and result in a low but non-zero probability for MEC to remain following implementation, so LUCs are included as part of the alternative to promote and maintain user awareness. This alternative is proposed only for consideration for the Range Complex No. 1 MRS since it includes areas with the greatest probability for exposure and for subsurface MEC to be present.

Alternative 5, **Surface Clearance, Subsurface Clearance, Tree Survey and Clearance, and LUCs**, provides the greatest reduction in explosive hazard and the most permanent and effective solutions for the long term in the clearance areas. Alternative 5 was retained only for the Range Complex No. 1 MRS because of the potential for subsurface MEC to be present. Based on the MEC HA results, subsurface clearance reduces the hazard ranking from the high potential hazard conditions (Hazard Level 2) to moderate potential hazard conditions (Hazard Level 3) for the Range Complex No. 1 MRS. This is the greatest hazard reduction indicated among all of the alternatives. Alternative 5 was not retained for the Range Complex No. 1 (a) MRS or the Range Complex No. 1 (b) MRS because of the lack of evidence of an impact or target area.

Under this alternative, all anomalies with signals that exceed a specified threshold are excavated and result in a low but non-zero probability for MEC to remain following implementation, so LUCs are included as part of the alternative to promote and maintain user awareness. This alternative is proposed only for consideration for the Range Complex No. 1 MRS since it includes areas with the greatest probability for exposure and for subsurface MEC and MEC imbedded in trees to be present.

11.3.3 Short-Term Effectiveness

Short-term effectiveness considers worker and community safety, as well as ecological and cultural impacts associated with implementing each alternative for the MRSs. Worker and community safety is addressed through LUCs such as exclusion zones or other access limitations. Ecological impacts could be related to disturbance during clearance activities.

Alternative 1, NA has no short-term impacts to site workers, visitors, or the environment so short-term effectiveness is high. There would be no limitations to access, or safety risks for site workers, and there would be no ecological disturbance associated with this alternative.

Alternative 2, LUCs for Site Visitors and Site Workers has negligible short-term impacts to visitors or the environment related to installation of ECs such as signs or fencing. There would be minimal impacts on ecological receptors as well.

Alternative 3, Surface Clearance and LUCs, would pose some risk to site workers due to the physical challenges of working in varied terrain, and the potential for exposure to MEC hazards. There is some potential for environmental impacts if any vegetation must be removed as part of the action. The Range Complex No. 1 MRS is the only area considered for surface clearance. For MEC disposal activities, some site access limitations would be temporarily imposed to ensure both worker safety and to keep site visitors well outside the area. These exclusions would be limited to the short timeframe required to set up and complete the disposal activities. If MEC will be consolidated to a central location prior to disposal, appropriate exclusion and limits to access would be employed to ensure protection of all site workers and visitors, but these limitations also would be limited in extent and duration.

Alternative 4, Surface Clearance, Subsurface Clearance, and LUCs, would pose the next greatest risk to site workers due to the subsurface excavation activities required in addition to surface clearance hazards and terrain challenges. There would be short-term environmental effects because of the excavations performed and possible requirements for vegetation removal. Based on the subsurface investigation performed during the RI, the excavations would not be expected to be much deeper than 18 inches, and would be manually performed. Only small mechanized equipment (e.g., walk behind brush hog) would be used for vegetation removal. No mechanized equipment that could cause more short-term environmental impacts would be used. Following the removal of the MEC or MD associated with the anomalies, the holes would be backfilled. Additionally, the excavation procedures could specify that the native vegetation be preserved and replaced upon backfilling to minimize the impacts or to be re-seeded with native grasses.

The short-term risks related to MEC disposal and handling would be the same as for surface clearance with the possible difference in the number of disposal operations required because greater numbers of MEC items could be found. For MEC disposal activities, some site access limitations would be temporarily imposed to ensure both worker safety and to keep site visitors well outside the area. These exclusions would be limited to the short timeframe required to set up and complete the disposal activities. If MEC can be consolidated to a central location prior to disposal, appropriate exclusion and limits to access would be employed to ensure protection of all site workers and visitors, but these limitations also would be limited in extent and duration.

Alternative 5, **Surface Clearance, Subsurface Clearance, Tree Survey and Clearance, and LUCs**, would pose the greatest risk to site workers due to the timber harvesting activities required in addition to surface and subsurface clearance hazards and terrain challenges.

The short-term risks related to MEC disposal and handling would be the same as for surface and subsurface clearances with the possible difference in the number of disposal operations required because greater numbers of MEC items could be found. For MEC disposal activities, some site access limitations would be temporarily imposed to ensure both worker safety and to keep site visitors well outside the area. These exclusions would be limited to the short timeframe required to set up and complete the disposal activities. If MEC can be consolidated to a central location prior to disposal, appropriate exclusion and limits to access would be employed to ensure protection of all site workers and visitors, but these limitations also would be limited in extent and duration. The removal of MEC hazards from trees is extremely hazardous since MEC would likely require a BIP while the tree is still intact. This poses the risk of the tree falling while the MEC is destroyed or the possible ignition of a forest fire.

11.3.4 Implementability

Implementability considerations include both technology and administrative requirements associated with performing each alternative. Technical requirements are related to site access issues such as terrain, accessibility in terms of the distance from roads or trails that must be navigated to perform the field activities, available technologies, and availability of equipment and trained personnel. Administrative requirements include access due to ownership, coordination required to schedule and perform site activities, timeframe for implementation, any legal considerations, and funding availability. The tree survey and clearance alternative addresses all media and receptors that could potentially contain MEC and MC and is considered the Unrestricted Use/Unrestricted Exposure (UU/UE) alternative.

Alternative 1, NA requires no technology or administrative coordination to implement, so it ranks highest in terms of ease of implementability.

Alternative 2, LUCs for Site Visitors and Site Workers could be quickly implemented over the majority of the MRSs. Stakeholders would need to coordinate to prepare the ICIAP, and the USACE would need to identify funding mechanisms. The expertise and professional services are readily available to develop the elements that would likely be included, such as training materials and informational signs, and UXO technicians. Coordination among stakeholders would be required to develop a final plan. Primary considerations for implementing these alternatives are the need to determine funding sources and stakeholder responsibilities for:

- Preparing and distributing materials, maintaining a website
- Monitoring and replacing signs as needed
- Installation of fencing

Implementing and enforcing deed restrictions on privately owned land will be difficult and likely impossible. The majority of the MRS impacted by munitions is owned by the City of Port Angeles and would likely not have any issues implanting such restrictions.

Alternative 3, Surface Clearance and LUCs is possible for the Range Complex No. 1 MRS. Surface clearance could be implemented at this location with the exception of any areas too steep or heavily vegetated for access. This alternative was not retained for the remaining MRSs because they are not likely impacted by munitions. These observations were based on extensive visual survey coverage, so the potential for MEC/MD remaining within these MRSs is considered to be low.

The Range Complex No. 1 MRS is mostly accessible from existing roads and trails. This MRS is located within property owned and managed by the City of Port Angeles; therefore, access coordination would only need to be addressed with the City of Port Angeles. Field teams performing surface clearance would need to include certified UXO technicians. Field equipment includes analog geophysical sensors (e.g., Schonstedt magnetometers) and a GPS unit to record recovered features. The field season is generally unlimited; however, the time of year with more sunlight would be preferable (April until September). Field efforts also would require coordination with the WDOE to ensure compliance with ARARs related to wildlife protection to ensure there would be no disturbance of wildlife as required during nesting and breeding seasons. There are no significant implementability issues associated with this alternative.

Alternative 4, Surface Clearance, Subsurface Clearance, and LUCs, is applicable for the Range Complex No. 1 MRS. This alternative is implementable and would consider the same factors as described above for Alternative 3.

Alternative 5, Surface Clearance, Subsurface Clearance, Tree Survey and Clearance, and LUCs, is applicable for the Range Complex No. 1 MRS. This is the location where there is greater potential for exposure to MEC imbedded in trees. This alternative is considered implementable; however, it is anticipated that some of the trees that contain the potential to contain MEC may not be accessible. Other factors that would need to be addressed compared to Alternatives 3 and 4 include the greater potential for forest fires and overhead hazards due to falling trees, and the evaluation/removal of MEC imbedded in trees. Alternative 5 is considered the least implementable compared to the other Alternatives.

11.3.5 Cost

Comparison of costs should be based on the relative order-of-magnitude among the identified alternatives for each MRS. Estimates should represent net present value costs for all components of the alternative, including initial capital costs and any post-removal monitoring costs as appropriate. As recommended in the CERCLA guidance (USEPA, 1988), the desired level of accuracy for this stage of the process is -30% to +50%.

Alternative 1, NA requires no action and therefore has no implementation costs.

Alternative 2, LUCs for Site Visitors and Site Workers costs are the lowest among the alternatives that would require any effort to implement. There are no field deployment costs associated with the primary activities of preparing and updating the ICIAP, maintaining the website, and developing and distributing training and informational materials. Some minimal level of field activity would be required for installing or replacing road and trail signs, and if determined necessary, fencing. This alternative would require long-term implementation to monitor and replace or install signage and fencing, maintain and update the website, distribute informational material, and review and update the ICIAP. If the property were to be transferred from within the MRS impacted by munitions (Range Complex No. 1), the LUCs would need to be incorporated into the property transfer documents.

Table 11-1 Cost Breakdown: LUCs for Site Visitors and Workers

Materials	Field Work	Planning Documents	Project Management	Reporting	Fence Installation	10% Contingency	Total Estimate
$14.6K	$28.8K	$49.5K	$5.0K	$35.3K	$322.3K	$45.6K	**$501.1K**

Alternative 3, Surface Clearance and LUCs costs assume 100% clearance for the Range Complex No. 1 MRS. Cost components included preparation of planning documents and the field effort required to perform the clearance activities. Estimates included the labor, equipment, and costs associated with MEC destruction and MD demilitarization and recycling. LUC costs were also incorporated as developed for Alternative 2. Relative costs for this alternative is lower than for subsurface clearance.

Table 11-2 Range Complex No. 1 Surface Clearance and LUCs

LUCs	Surface Clearance Cost	Planning Docs	Project Management	Land Survey	Reports	10% Contingency	Total Estimate	Cost per Acre
$501.1K	$288.6K	$80.2K	$41.3K	$38.0K	$81.6K	$103.1K	**$1,133.9K**	**$10.7K**

Alternative 4, Surface Clearance, Subsurface Clearance, and LUCs costs are the next highest relative costs among the alternatives due to the additional level of effort required to remove the subsurface MEC hazard.

Table 11-3 Range Complex No. 1 Surface Clearance, Subsurface Clearance, and LUCs

LUCs	Surface and Subsurface Clearance Cost	Planning Docs	Project Management	Land Survey	Reports	10% Contingency	Total Estimate	Cost per Acre
$501.1K	$1,493.2K	$80.2K	$94.5K	$38.0K	$81.6K	$228.9K	**$2,517.5K**	**$23.8K**

Alternative 5, Surface Clearance, Subsurface Clearance, Tree Survey and Clearance, and LUCs costs are the highest relative among the alternatives due to the significant level of effort required to remove the subsurface hazard and remove the MEC imbedded in trees.

Table 11-4 Range Complex No. 1 Surface Clearance, Subsurface Clearance, Tree Survey and Clearance, and LUCs

LUCs	Surface and Subsurface Clearance Cost	Planning Docs	Project Management	Land Survey	Tree Survey and Clearance	Reports	10% Contingency	Total Estimate	Cost per Acre
$501.1K	$1,493.2K	$80.2K	$94.5K	$38.0K	$616.6K	$81.6K	$290.5K	**$3,195.7K**	**$30.2K**

The scores, summed scores, and rankings for applicable alternatives for each MRS to provide a guide to identify the alternative that is the most practicable solution to reducing or eliminating the MEC exposure hazard is presented in **Table 11-5**.

11.4 Conclusions

The information presented within this RI/FS report is intended to assist stakeholders with selecting the most appropriate alternative and to proceed with the next steps of the CERCLA and MMRP process. Once the project team agrees upon a preferred alternative a PP will be prepared. The PP will be presented to the local community at a meeting for input. A formal public comment period will be held for a minimum of 30 days. At the completion of the PP public comment period, any comments received will be addressed by the USACE. A DD will document the selected alternative and the intent to scope further munitions response actions, if any.

Table 11-5 Detailed Analysis of Alternatives

	Threshold Factors				Balancing					
	Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Pass/ Fail**	**Long-Term Effectiveness and Permanence**	**MECH HA Hazard Level/Score**	**Reduction of Toxicity, Mobility, or Volume by Treatment**	**Short-Term Effectiveness**	**Implementability**	**Value**
1	No Action	Not protective of human health and the environment. No source reduction. No reduction of future hazards	Yes.	Fail	Would not provide any long-term effectiveness or permanence.	2/780	No reduction of source area toxicity, mobility, or volume.	No short-term risks due to no actions required.	Highly implementable due to no actions required.	$0
2	Land Use Controls	Fencing and signs reduce interaction with MEC, thus reducing risk. Source remains; however, and access, although prohibited, is possible.	Yes, should be able to implement LUCs since the majority of the MRS is owned by the City of Port Angeles.	Pass	Can be effective at reducing possible receptor interaction.	2/780	No reduction of source area toxicity, mobility, or volume.	Limited short-term impacts associated with fence/sign installation.	Readily implementable, though installation and maintenance could be challenging due to the location and possible future funding constraints.	$501.1 K
3	Surface Clearance and LUCs	Source area reduction achieved via surface clearance of MEC. Further mitigate residual MEC hazards by reducing potential for interaction via LUCs.	Yes, work plans will identify appropriate protection of any wetlands and sensitive species. Any IDW will be managed and disposed of. All personnel utilizing explosives will be licensed by the State of Washington to acquire, possess, handle and use explosives.	Pass	Provides short-term effectiveness due to MEC source removal from the surface and the implementation of LUCs; however, residual MEC will be present.	3/565	Provides source area reduction of toxicity, mobility, or volume in MEC contaminated areas.	Possible short-term impacts associated with MEC removal.	Readily implementable; clearance requires qualified UXO technicians and specific equipment.	$1,133.9 K
4	Surface Clearance, Subsurface Clearance, and LUCs	Source area reduction achieved via surface clearance of MEC. Further mitigate residual MEC hazards by reducing potential for interaction via LUCs.	Yes, work plans will identify appropriate protection of any wetlands and sensitive species. Any IDW will be managed and disposed of. All personnel utilizing explosives will be licensed by the State of Washington to acquire, possess, handle and use explosives.	Pass	Provides short-term effectiveness due to MEC source removal from the surface and the implementation of LUCs; however, residual MEC may be present embedded within tree trunks.	3/545	Provides source area reduction of toxicity, mobility, or volume in MEC contaminated areas.	Possible short-term impacts associated with MEC removal.	Readily implementable; clearance requires qualified UXO technicians and specific equipment.	$2,157.5 K
5	Surface Clearance, Subsurface Clearance, Tree Survey and Clearance, and LUCs	Source area removal achieved by complete removal of MEC. Further mitigate residual MEC hazards by reducing potential for interaction via LUCs.	Yes, work plans will identify appropriate protection of any wetlands and sensitive species. Any IDW will be managed and disposed of. All personnel utilizing explosives will be licensed by the State of Washington to acquire, possess, handle and use explosives.	Pass	Provides long-term effectiveness due to MEC source removal from surface, subsurface, and the implementation of LUCs.	3/545	Provides source area reduction of toxicity, mobility, or volume in MEC contaminated areas.	Possible short-term impacts associated with MEC removal.	Partially implementable; clearance requires qualified UXO technicians and specific equipment. Access to all of the trees that would have been present when the range was operations would be difficult and robust safety protocols would be required.	$3,195.7 K

Notes:
IDW – Investigation Derived Waste
LUC – Land Use Control
MEC – Munitions and Explosives of Concern
UXO – Unexploded Ordnance

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