DRAFT FINAL
REMEDIAL INVESTIGATION/FEASIBILITY STUDY REPORT
SMALL ARMS RANGES

CAMP BONNEVILLE
VANCOUVER, WASHINGTON

December 12, 2006

PREPARED FOR
BONNEVILLE CONSERVATION
RESTORATION AND RENEWAL TEAM

PREPARED BY:

BAKER

TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS - Continued

LIST OF FIGURES – Continued

LIST OF ACRONYMS AND ABBREVIATIONS

Army	Department of the Army
bgs	below ground surface
BCT	BRAC Cleanup Team
BRAC	BRAC Base Realignment and Closure
ca	carcinogen
CFR	Code of Federal Regulations
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CLAP	contract laboratory program
COPC	chemical of potential concern
CRREL	U.S. Army Cold Regions Research and Engineering Laboratory
CSM	Conceptual Site Model
DQO	data quality objective
Ecology	Washington State Department of Ecology
EDF	electronic data format
EO	exploded ordnance
EPA	U.S. Environmental Protection Agency
FBI	Federal Bureau of Investigation
FSP	Field Sampling Plan
GIS	geographic information system
HASP	health and safety plan
HSO	health and safety officer
HE	high explosive
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
ID	investigation-derived waste
ITR	Independent Technical Review
µg/L	micrograms per liter
MDL	method detection limit
MRL	method reporting limit
MTCA	Model Toxics Control Act
NC	nitrocellulose
NC	noncarcinogen
NG	nitroglycerine
NGVD	National Geodetic Vertical Datum
NQ	nitroguanadine
OB	open burning
OD	open detonation
PA	picric acid
PCBs	polychlorinated biphenyls
PE	performance evaluation
PETN	pentaerythitol tetranitrate
Pt	Troutdale formation
PVC	polyvinyl chloride
Qa	quaternary flood plain
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
Qls	quaternary landslide deposit

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
SAP	sampling and analysis plan
SASR	Supplemental Archive Search Report
SI	Site Investigation
SOW	Statement of Work
SVOC	semivolatile organic compound
TBD	To Be Determined
TCRA	Time Critical Removal Action
TNT	2,4,6-trinitrotoluene
TPH	total petroleum hydrocarbons
Tv	volcanic bedrock
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
UST	underground storage tank
URS	URS Greiner Woodward Clyde
UXO	unexploded ordnance
VOC	volatile organic compound
WAC	Washington Administrative Code

1.0 INTRODUCTION

This document presents the results of a remedial investigation/feasibility study (RI/FS) of the Small Arms Ranges at the Camp Bonneville Military Reservation (Camp Bonneville). The Small Arms Ranges remedial investigation (RI) included the soil investigation of 17 Small Arms Ranges. The RI was conducted to characterize soils at these areas at Camp Bonneville in order to provide data upon which to base decisions for further actions. Based on the results of the RI, the feasibility study (FS) was conducted to identify and evaluate cleanup action alternatives and select a cleanup action for the Small Arms Ranges. This RI/FS was conducted by the Department of the Army (Army) in accordance with the requirements of the Washington Model Toxics Control Act (MTCA) regulations, which are contained in Chapter 173-340 of the Washington Administrative Code (WAC 173-340).

The original formation of this document was completed under a Department of the Army Fort Lewis, Washington GSA Contract Number GS-10F-0028J for the Washington Department of Ecology (WDOE) in March 2005. The original preparers were Calibre. The document has been modified slightly in order to reflect the changes in the ownership of the Camp Bonneville property and in the identities of the consultants and contractors conducting the work under this new ownership.

1.1 Site Background

Camp Bonneville is located in southwestern Washington and comprises approximately 3,840 acres (see **Figure 1**). Camp Bonneville is located approximately five miles east of the Vancouver City Limits in Clark County. The Army used Camp Bonneville for live fire of small arms, assault weapons, artillery, and field and air defense artillery between 1910 and 1995. In the early 1950s, the Defense Department arranged to lease an additional 840 acres from the State of Washington to expand training possibilities off the post. The facility has been used for weekend and summer training by the U.S. Army Reserve units in Southern Washington and Northern Oregon and is currently a sub-installation of Fort Lewis. Other Reserve and National Guard components, as well as the Federal Bureau of Investigation (FBI) and local law enforcement units, have also used the site.

Camp Bonneville is more particularly described in U.S. Public Land Survey terminology as follows:

- The site is located in Range 3 East relative to the Willamette Primary Meridian. It includes the following parcels in Township 2 North:
  - Section 1 – all (640± acres) – owned
  - Section 2 – all (640± acres) – owned
  - Section 3 – all excepting two parcels along the western boundary of Section 3 (618± acres) – owned;
  - Section 10 – North ½ (320± acres) – owned
  - Section 11 – Northwest ¼ except the southeast triangular ½ of southeast ¼ of this ¼ and the northwest ¼ of northeast ¼ (200± acres) – leased from Washington State Department of Natural Resources

- The following parcels are located in Township 3 North:
  - Section 34 – Southeast ¼ (160± acres) – owned
  - Section 35 – all (640± acres) – owned
  - Section 36 – all (640± acres) – leased from Washington State Department of Natural Resources

In July of 1995, Camp Bonneville was selected for closure under the 1995 Base Realignment and Closure (BRAC) process. Since the camp was officially closed, investigations were conducted by the Army and its consultants in order to characterize the nature and extent of contamination at the site and to develop a plan for potentially transferring ownership. Clark County (County) expressed interest in the site and began the process for obtaining the property by developing a Reuse Plan. The reuse plan developed called for the majority of Camp Bonneville to be transferred to Clark County (County) for the public benefit – education, law enforcement, and parks, with no financial gain to the county.

In October 2006 the Army transferred ownership of the property to the County which subsequently and immediately transferred ownership to the Bonneville Conservation Restoration and Renewal Team, LLC (BCRRT). BCRRT will hold the deed of the property during investigation and clean-up activities at the site. After the property is cleaned to WWDOE standards, BCCRT will transfer the property back to the County. The County will then begin implementing the reuse plan.

This RI/FS report describes the findings of completion of a remedial investigation and feasibility study conducted on the Small Arms Ranges.

The Small Arms Ranges RI consisted of investigating two areas at the firing ranges as follows:

- Seventeen (17) areas that were used as small arms firing ranges, and
- Twelve (12) muzzle blast zones of firing ranges where the firing lines were known.

For administrative reasons, the Camp Bonneville site is divided into three Remedial Action Units. The Remedial Action Units established at Camp Bonneville include the following:

- Remedial Action Unit 1: The unit consists of 20 acres where hazardous substances (other than ammunitions) have been found.
- Remedial Action Unit 2: The unit is divided into three subunits, as follows:
  - Remedial Action Unit 2A consists of the small arms range areas.
  - Remedial Action Unit 2C consists of two demolition areas know as Demolition Area s 2 and 3.
  - Remedial Action Unit 2C is the site of a former combined landfill and demolition area know as Landfill 4 / Demolition Area 1.

- Remedial Action Unit 3: The area includes the entire site where ammunition residuals (including unexploded ordnance) may be found.

In addition to the investigation findings and cleanup actions proposed in this document, the Army is investigating and determining cleanup needs at other areas within Camp Bonneville that include other areas within Remedial Action Unit 2 and the other Remedial Action Units.

1.2 Objectives of the RI/FS

The following describes the objectives of the RI and the FS for the Small Arms Ranges.

The objectives of the RI were to:

- Provide data needed to determine whether actions are required because of soil contamination at the Small Arms Ranges; and

- If actions are required, to provide data needed to select these actions.

The objectives of the FS were to:

- Identify cleanup action alternatives that will meet cleanup action objectives for Small Arms Ranges; and

- To provide information needed to select preferred cleanup action alternatives for Small Arms Ranges that satisfy the requirements of WAC 173-340-360.

The Army implemented RI activities at the Small Arms Ranges in 2002 and 2003. The specific actions conducted to obtain the data required to meet the RI objectives and the results of the investigations are presented in **Section 3.0**, Field Investigations. The general investigative approach at each of the 17 Small Arms Ranges investigated was designed to collect the following data:

- The concentration of lead residues in the top 0-6 inches of soil at 307 sample areas (one-half acre grids) within firing ranges.
- The background concentrations of lead in 20 samples from the top 0-6 inches of soil at undisturbed/unused locations within Camp Bonneville.
- The concentrations of explosive residues in soil in 12 muzzle blast areas of the firing ranges where the firing location is known.

The specific sampling and analysis protocol used to collect the RI data at each of the 17 ranges, and the muzzle blast zones at 12 of these ranges, along with the number of samples collected, sample location, and analyses are presented in **Section 3.0**.

1.3 General Site Information

This section contains the following general facility information required by WAC 173-340-

350(7)(c)(i):

Project title: Remedial Investigation and Feasibility Study Report for Small Arms Ranges:

Project coordinators: Name: Michael Gage
Address: Bonneville Conservation Restoration and Renewal Team, LLC
23201 Northeast Pluss Road
Vancouver, WA 98682

Phone number: (360)566-6990

Facility location: The Small Arms Ranges investigated are within the boundaries of Camp Bonneville that is located in southwestern Washington, approximately 5 miles east of the Vancouver City limits in Clark County (see **Figure 1**). Locations of the 17 Small Arms Ranges investigated are presented in **Figure 2**. Figures of each of the 17 Small Arms Ranges investigated are presented within this report. Camp Bonneville is located in Sections 34 and 35, Township 3 North, Range 3 East and Sections 1, 2, 3, and 10 Township 2 North, Range 3 East.

Dimensions of facility: Camp Bonneville encompasses approximately 3,840 acres. The numerous areas investigated during the RI, range in size from less than an acre to several acres in size. The dimensions of the area investigated at each of the specific areas are presented in the description of the sampling conducted in **Section 3.0**.

Present owner and operator: Camp Bonneville and the Small Arms Ranges investigated are owned and operated by the Bonneville Conservation Restoration and Renewal Team, LLC.

Chronological listing of past owners and operators and operational history: The Department of the Army owned and operated the Camp Bonneville site since the early 1900's through October 2006. In October 2006 the Army transferred ownership of the property to the County which subsequently transferred the land to the BCRRT. Camp Bonneville was used by the Army as firing range for small arms, artillery, and other munitions from the approximately 1910 through 1995. The BCRRT will hold the deed of the property during investigation and clean-up activities at the site. After the property is cleaned to Washington Department of Ecology (WDOE) standards the BCCRT will transfer the property back to the County

1.4 Report Organization

This section of the RI/FS report presented introductory information, including background on the activities leading up to this RI/FS, the purpose of the RI/FS, and general site information required by WAC 173-340-350(7)(c)(i). **Section 2.0** presents information on site conditions required under WAC 173-340-350(7)(c)(iii). This information includes that developed during this RI, as well as information developed during previous investigations at Camp Bonneville. Field activities that were conducted during this RI are described in **Section 3.0**. **Section 4.0** discusses the evaluation of human health and ecological risks. **Section 5.0** presents conclusions with respect to on-site contamination and the need for cleanup actions, and presents remedial

objectives. **Section 6.0** then identifies general response actions based on these conclusions and objectives. Specific cleanup technologies applicable to the site are identified in **Section 7.0**. **Section 8.0** identifies cleanup action alternatives, evaluates these alternatives with respect to the requirements contained in WAC 173-340-360, and identifies the preferred cleanup actions for Small Arms Ranges. References are presented in **Section 9.0**.

2.0 SITE CONDITIONS

This section presents descriptions of site conditions relevant to the RI/FS. **Section 2.1** presents the general facility conditions identified in WAC 173-340-350(7)(c). **Sections 2.2** through **2.7** address the specific characteristics identified in WAC 173-340-350(7)(c)(ii) through (iii), respectively. Many of these conditions have been characterized by previous investigations at Camp Bonneville. As appropriate, the results of investigations at the sites are summarized in this section. Where required information was not available from previous investigations, additional data were obtained from RI activities, including the field investigations described in **Section 3.0**.

2.1 General Site Conditions

This section presents a summary of site conditions, including a site conditions map as required by WAC 173-340-350(7)(ii).

Camp Bonneville comprises approximately 3,840 acres and is located in southwestern Washington approximately 5 miles east of the Vancouver City limits in Clark County. Camp Bonneville was officially closed in 1995 and is currently owned by the BCRRT. The Army used Camp Bonneville for live fire of small arms, assault weapons, artillery, and field and air defense artillery between 1909 and 1995. A portion of the property (840 acres) is leased from the State of Washington. The facility has been used for weekend and summer training by the U.S. Army Reserve units in Southern Washington and Northern Oregon, other Reserve and National Guard components, FBI, and local law enforcement units. Camp Bonneville was included on the 1995 Base Realignment and Closure (BRAC) list.

Camp Bonneville is mostly undeveloped forested hillsides and creek side drainages. Former military barracks and training facilities are concentrated at Camp Killpack and Camp Bonneville cantonment areas, which cover approximately 30 acres. Other developed areas include firing ranges, a paved two-lane road connecting the main gate with the two containment areas, and a network of unpaved roads. The main gate to Camp Bonneville is located on the western boundary of the camp, approximately one mile north of Pluss Road.

Camp Bonneville site condition maps are shown on **Figures 2** and **3**. The known site conditions of the Small Arms Ranges investigated during the RI and the general sampling strategy are as follows:

Small Arms Ranges

The Small Arms Ranges have been used as firing ranges for a variety of weapons training. Approximately 25 potential ranges have been identified from maps dating back to 1958. The firing ranges were used for small arms, large-caliber machine guns, rifles, grenades, light anti-tank weapon rockets, and subcaliber weapons. Seventeen firing ranges were identified for investigation during the RI. Of the original 25 potential ranges, some had historically different names and were determined to be at the same location and double counted.

The RI at the Small Arms Ranges was designed to evaluate the potential for soil contamination.

The Small Arms Ranges site condition maps are shown on **Figures 2** and **3**. The soils at 17 Small Arms Ranges were sampled to identify/evaluate the presence of lead and/or explosives residues in shallow soil. Previous investigations at other ranges have detected lead and other metals in range soils (ITIR 2003). Soil samples were collected from half-acre grids across all the 17 Small Arms Ranges (307 half-acre grids were sampled). All range samples were analyzed for lead. Samples collected in the muzzle blast zones were analyzed for explosives. Areas excluded from this soil-sampling program are target areas/impact zones, and firing lines. These excluded areas will be covered separately by investigations and/or removal actions.

Background soil samples were collected as part of the Small Arms Ranges investigation. Soil samples from suitable background areas within Lacamas Valley were collected and analyzed for lead using EPA Method 6010. Twenty (20) background soil samples were collected and analyzed.

2.2 Geology and Hydrogeology

A detailed summary of existing information on the geology and hydrogeology of the Camp Bonneville area has been prepared in prior investigation reports. The following sections provide excerpts of the information previously prepared (URS 2001) and information collected during conduct of the RI at Camp Bonneville.

2.2.1 Regional Geology and Physiography

Camp Bonneville is situated on the margin of the western foothills of the southern Cascades in the transition zone between the Puget Trough and the Willamette Trough Provinces. The geology of this area generally consists of Eocene and Miocene volcanic and sedimentary rock types overlain by unconsolidated clays, silts, sands, and gravels of the Troutdale Formation (Phillips 1987).

The area surrounding Camp Bonneville is sparsely populated with scattered residences and is used primarily for agriculture and livestock grazing. The nearest town is Proebstel, an unincorporated community about 2.5 miles to the southwest of the western entrance to the camp. The two cantonments, Camp Killpack and Camp Bonneville, are located on the valley floor. The remainder of Camp Bonneville consists of moderately steep, heavily vegetated slopes that have been used primarily as firing ranges. The valley floor is a relatively narrow floodplain, which ranges from an elevation of about 290 feet National Geodetic Vertical Datum (NGVD) on the western end of Camp Bonneville to about 360 feet NGVD on the east. The adjoining slopes rise moderately steeply to elevations between approximately 1,000 and 1,500 feet NGVD along ridge tops within the property boundaries. The entire installation is heavily vegetated.

2.2.2 Surface Water and Sediments

The principal surface water feature in the vicinity of the investigation area is Lacamas Creek, which flows southward from the confluence of two branch streams in the north-central part of Camp Bonneville, exiting the installation at its southwest corner.

From the southwestern property boundary, Lacamas Creek flows southwestward to Proebstel, where it turns toward the southeast and continues to its confluence with the Columbia River at the town of Camas. Numerous minor tributaries, that drain adjacent uplands, flow into Lacamas Creek. Buck Creek and David Creek, the largest of these streams, drain the southeastern hills of Camp Bonneville.

Two artificial impoundments of Lacamas Creek, with a total surface area of less than 4,600 square feet, have been created to support a trout sports fishery. Recently, the impoundments have been drained. Sediments of concern at Camp Bonneville only include the sediments within the Popup Pond that are being investigated separately from this RI.

2.2.3 Geology and Soils

Camp Bonneville is situated along the structural and physiographic boundary between the western flank of the southern Cascade Mountains and the Portland-Vancouver Basin. The geology of the Camp Bonneville vicinity is known primarily from geologic mapping by Mundorff (1964) and Phillips (1987), a limited number of well logs available from the general area, and a Multi-Sites Investigation conducted by Shannon & Wilson (1999a).

The geology at Camp Bonneville can be divided into three general areas that correspond approximately to topographic divisions. The area west of Lacamas Creek is composed of a series of predominantly gravel and semi-consolidated conglomerate layers with scattered lenses and stringers of sand (Upper Troutdale Formation).

Underlying the Troutdale Formation and comprising the area to the north and east of Lacamas Creek are predominantly basalt flows and flow breccia, with some pyroclastic and andesitic rocks that are folded and faulted. The bottomland along Lacamas Creek is composed of unconsolidated silt, sand, and gravel valley fill, with some clay. Because of the thick soil and dense vegetation, faults have not been identified within Camp Bonneville (Environmental Science and Engineering, Inc. [ESE] 1983).

The Camp Bonneville soils are mainly low-permeability clays, which results in considerable runoff after storms and occasional minor flooding of Lacamas Creek. Upland soils have mainly developed from basalt and are generally gravelly or stony and fairly shallow. Bottomland soils along Lacamas Creek tend to be clayey (Geo Recon International 1981). Shannon & Wilson (1999a) described the four distinctive stratigraphic units that underlie Camp Bonneville:

- Quaternary floodplain and stream channel alluvium and lacustrine deposits, which mantle the Lacamas Creek valley floor (Qa).
- A Quaternary landslide deposit (Qls) of surface soils and bedrock displaced from the steep slope along David Creek.
- A thick sequence of Quaternary to Pliocene-age gravel, fine-grained sand, and sand with cobbles and boulders known as the Troutdale Formation (Pt), which underlies areas to the west of the Bonneville cantonment.

- Oligocene volcanic bedrock (Tv), which is exposed at the surface in the eastern part of Camp Bonneville.

Quaternary alluvium deposits comprise the shallow surface soils of the Lacamas Creek valley floor, which is composed of stream channel, floodplain, and alluvial fan sediments. These deposits are expected to consist of a thin layer of clay and silt, underlain by layers of sand/silt and clay. During drilling and excavation activities associated with the removal of an underground storage tank (UST) in Camp Killpack (Hart Crowser 1996), at least 25 feet of silty clay was encountered and interpreted to be older alluvium. Borings from the Multi-Sites Investigation (Shannon & Wilson 1999a) also encountered alluvial clays and silts overlying a relatively thick, silty clay deposit in the Camp Bonneville cantonment. These clayey soils probably originated as water borne sediments that were deposited on the valley floor in Quaternary time as a result of catastrophic flooding along the Columbia River (Shannon & Wilson 1999a).

The Troutdale Formation, which underlies the western-most portion of the camp, ranges from poorly consolidated sand and gravel to a well indurated conglomerate in its upper part. Based on regional boring logs, the Upper Troutdale Formation locally is about 150 feet thick and consists of cemented sand, gravel, sandy clay, and boulders. It is underlain by up to 150 feet of the Lower Troutdale Formation, which contains considerably more clay interspersed with sandy and gravelly layers. There is considerable variation in the lithology and thickness of the Troutdale Formation. In general, the formation thins eastward against the underlying bedrock, and the lower part of the formation reportedly is typically coarser grained toward the east (Mundorff 1964).

The bedrock that underlies the alluvial deposits and Troutdale Formation is exposed at the surface in the eastern part of Camp Bonneville. This bedrock consists of Oligocene-age andesite and basaltic andesite flows, minor flow breccias, tuffs, and volcaniclastic sandstones. According to the logs of borings from the Multi-Sites Investigation (Shannon & Wilson 1999a), the uppermost bedrock is severely weathered. This weathered bedrock tends to form surface soils that contain gravel of basalt lithology. During drilling for the Multi-Sites Investigation, bedrock was encountered in 10 soil borings at depths ranging from approximately 6 to 37 feet below ground surface (bgs).

2.2.4 Regional Hydrogeology

Limited information is available about the hydrogeology of Camp Bonneville. Most prior work throughout the Clark County area has focused on the Troutdale Formation (as described in Mundorff 1964). Camp Bonneville resides over the eastern edge of the Troutdale Formation where it is pinched out by the underlying bedrock. There are two drinking water wells at Camp Bonneville: a 385-foot-deep well at the Camp Bonneville cantonment, and a 193-foot-deep well at the Camp Killpack cantonment (ESE 1983). The latter well is apparently different from the 516-foot-deep well at the Camp Killpack cantonment described by Mundorff (1964). In addition, a well was drilled at the Federal Bureau of Investigation (FBI) range during 1998, which extends to a depth of 105 feet bgs (Shannon & Wilson 1999b). Several groundwater monitoring wells associated with

the sewage lagoons are located east of the Camp Bonneville cantonment. Based on regional information from Mundorff (1964) and the reported depths of the wells at the camp, water supply wells in the area generally extend into the Troutdale Formation or underlying bedrock. Most of the nearby wells apparently obtain groundwater from depths of 150 to as much as 500 feet bgs.

The water table is typically within a few feet of the surface in areas underlain by alluvium and appears to fluctuate seasonally by several feet. A rising water table occurs in the early fall through spring during the rainy season, and a declining water table occurs throughout the summer. The localized groundwater flow generally follows local topography toward tributaries and creeks.

Generally, groundwater flows from the uplands towards Lacamas Creek. The elevation of the water table in the alluvial valley areas of Camp Bonneville is expected to be fairly shallow (in the range of 5-20 feet bgs) based on the presence of shallow bedrock, multiple creeks, tributaries, and boggy areas.

Two monitoring wells were installed as part of the investigation of Landfill 4, an upland area of Camp Bonneville (Shannon & Wilson 1999b). The depths to water in the wells ranged from 10.4 feet bgs to 18.8 feet bgs. The limited groundwater elevation data suggested a groundwater flow direction towards the creek, which is consistent with the surface topography.

Previous upgradient investigations (Landfill 4) detected explosives and volatile organic compounds in groundwater samples collected from specific wells. Other upgradient land uses that could have contributed chemicals of potential concern (COPCs) include firing ranges, open burning and open detonation grounds, and one or more underground storage tanks that have been removed.

Specific geologic and hydrogeologic data obtained during recent groundwater investigations at Camp Bonneville are presented in the following sections.

2.2.4.1 Groundwater Flow

Groundwater within the shallow alluvium and Upper Troutdale Formation flows horizontally toward Lacamas Creek from upland areas within the Lacamas Creek valley, which encompasses most of Camp Bonneville. The general groundwater flow is to the southwest through the Lacamas Creek Valley and groundwater leaves Camp Bonneville where Lacamas Creek exits the western boundary of the camp. A small area north of the Lacamas watershed appears to drain west into another watershed.

Based on monitoring wells recently installed in the area where Lacamas Creek intercepts the western boundary, and upgradient wells installed at Demolition Areas 2 and 3, the following observations were made:

- A mild downward vertical gradient occurs in wells located along the western boundary where the Upper Troutdale Formation is exposed at the surface and is unconfined.

- Where the Upper Troutdale in confined by overlying alluvium (near Demolition Area 3) an upward gradient (artesian well) was observed.

- Depths to water are approximately 10 feet bgs at the boundary area wells, 12 feet bgs at DA3, and approximately 5 feet bgs at DA2.

- Horizontal groundwater flow within the Upper Troutdale and alluvium typically follows the topographic contours within the Lacamas watershed and exits Camp Bonneville near the Lacamas Creek boundary area.

2.2.4.2 Groundwater Quality

Previous investigations at Landfill 4 detected explosive residues (RDX and HMX), and volatile organic compounds (VOCs) in groundwater samples collected from specific wells. Eight monitoring wells recently installed and sampled (January 2003) near where Lacamas Creek exits the Camp Bonneville boundary, showed no signs of contamination above applicable standards for explosives, metals, VOCs, SVOCs, or TPH compounds. Monitoring wells were also installed near Demolition Area 2 and Demolition Area 3. Monitoring of these wells is currently being conducted and the results of the groundwater investigation are being reported separately.

2.3 Air

Hazardous substances at the Small Arms Ranges are not of concern with respect to impacts to air quality. As shown in the CSM, the contaminants of concern are present in soil. Because of the non-volatile nature of the contaminants in surface and subsurface soils, it is unlikely that contaminants would affect the air at the sites. The Clean Air Act under Section 112(b) 3 (7) excludes elemental lead as a hazardous air pollutant. Disturbance of the soil through wind and/or human disturbance could cause dust and release the fine grain soil particles into the air. Dust and potentially contaminated soil could be transported in the air to different locations. Therefore, during soil disturbing actions at Camp Bonneville, controls should be implemented to reduce the generation of dust.

2.4 Conceptual Site Model

A conceptual site model (CSM) identifying sources of hazardous substances, pathways for contaminant migration, and potential receptors are shown in **Figure 4**. The information used to develop this CSM, and conclusions drawn from this CSM, are presented in the following sections

The CSM is intended as a schematic representation of potential pathways by which receptors (humans or other ecological endpoint species) may be exposed to chemicals at or released from a

source. The purposes of the CSM are to provide a framework for problem definition, to identify exposure pathways that may result in adverse effects to human health or other ecological receptors, to aid in identifying data gaps, and, if necessary, to aid in identifying applicable cleanup measures targeted at significant contaminant sources and exposure pathways. The exposure pathways in the conceptual site model are shown in **Figure 4**.

An exposure pathway describes a specific environmental pathway by which chemicals may be transported to human or other ecological receptors. A complete exposure pathway requires each of the following six elements:

- Source of chemicals
- Mechanism of chemical release
- Environmental transport medium
- Exposure point
- Intake route
- Human or other ecological endpoints

If one of these elements is absent, the pathway is incomplete and exposure cannot occur. Incomplete pathways, as well as negligible pathways that would not contribute to overall risk estimates, are not expected to result in adverse effects to human health or the environment.

2.4.1 Potential Release and Transport Mechanisms

The potential sources of COPCs are the lead in bullets and explosive residues near the firing lines. Contaminants emanating from these potential soil sources may migrate from near the soil surface to deeper soils and have the potential to enter groundwater and surface water. In addition, the COPCs can bind to soil and be transported by fugitive dust. The main release mechanisms for COPCs to the environment include:

- Leaching from potentially contaminated soil into deeper soils,
- Infiltration to groundwater, and
- Stormwater runoff and wind releasing soils to down slope/downwind areas.

Elemental lead from bullet slugs and bullet fragments can be transported as a particulate by the action of surface water, groundwater, and wind. Precipitation runoff and wind could distribute lead particulates and lead contaminated soil particles down slope or along the prevailing wind direction.

When lead is exposed to the atmosphere and precipitation, elemental lead will tend to oxidize or corrode over time. Oxidation products consist primarily of lead hydroxide and lead carbonates. As solids, lead and these oxidized compounds are nearly insoluble. Lead compounds show the greatest solubility at very acidic or alkaline conditions.

The potential migration of the COPC at the Small Arms Ranges, lead, is minimized because lead tends to bind strongly to soil particles. Therefore, it is unlikely that lead would migrate through the soils at the ranges and impact groundwater. Stormwater

and/or erosion could transport contaminated soil particles to surface water bodies. Investigations of potential groundwater and surface water contamination at Camp Bonneville have been conducted. There is no evidence of lead impacting surface water or groundwater at Camp Bonneville (Hart Crowser 2000 [surface water] and various investigations at Landfill #1, Demolition Area 2 and 3, boundary area wells, and quarterly monitoring [groundwater]). Results of these studies are being reported in separate investigative reports.

2.4.2 Potential Human Receptors

Potential human receptors include current and future on-site workers, future users of the site for recreation and training, and current and future offsite residents downgradient of the firing ranges. Hypothetical future onsite visitors and workers that are assumed to have unrestricted access to soil are included in the CSM. The potential exposure mechanisms to COPCs in soil consist of dermal contact, ingestion, and inhalation of on site soil.

2.4.3 Potential Ecological Receptors

Camp Bonneville is a heavily wooded area with Douglas fir, western red cedar, western hemlock, and red alder as the dominant tree species. Depending primarily on moisture gradients, the understory is composed of salal, Oregon grape, vine maple, and sword fern (Larson 1980 and GeoRecon International 1981). Several species of small mammals and birds reside on the site including cottontail rabbits, ground squirrels, mice, and shrews. Large mammals such as deer, bears, and cougars are also present at Camp Bonneville. There are also several special-status species present at or near Camp Bonneville. Species confirmed at or near Camp Bonneville include:

- Plants
  - Hairy-stemmed checker-mallow (state endangered species)
  - Small-flowered trillium (state sensitive species)
- Amphibians
  - Northern red-legged frog (federal species of concern)
- Birds
  - Vaux's swift (state candidate species)
  - Pileated woodpecker (state candidate species)
- Mammals
  - Brush Prairie (Northern) pocket gopher (state candidate species)
- Fish
  - Coastal Cutthroat Trout: federal species of concern.

Potential primary receptors on site include terrestrial animals that may be exposed to COPCs in surface and subsurface soils (i.e. burrowing animals). Terrestrial plants and waterfowl could also be exposed to COPCs in soils. Terrestrial animals and plants, benthic invertebrates, aquatic plants, and fish could be exposed to COPCs in surface water and sediments. Potential offsite exposure would involve direct exposure to soil released into the air. The potential exposure mechanisms to COPCs in soil consist of dermal contact, ingestion, inhalation, and uptake (plants).

2.5 Natural Resources and Ecology

It is unlikely that archaeological significant items will be discovered during current or future activities at the Small Arms Ranges. In the unlikely event that human remains or other archaeological significant items are encountered during field activities, work will cease in the area of the find and all materials will be left intact. The Contractor Manager will notify the BCRRT Project Manager within four hours of the find. The BCRRT Project Manager will contact the Clark County Sheriff's Department to ascertain whether the items are of recent origin. Should the Sheriff's Department determine that the items are associated with Native American burial practices, the BCRRT Project Manager will also notify the appropriate Native American tribal contacts for consultation about the nature and disposition of the items discovered.

A number of plant and vertebrate animal species that are either federally or state-listed as endangered or threatened, or are candidates for such listing, have either been documented at Camp Bonneville or are likely to occur there. These species are described in **Section 2.4.3**. Therefore, care will be required to avoid disruption of such species should they be present. If future actions are required at the Small Arms Ranges, field personnel will be directed to minimize disruption to plant and animal species, regardless of their protected status. Upon discovery of potentially sensitive habitats that could be harmed by site activities, measures will be taken to protect plants and animals from harm.

2.6 Hazardous Substance Sources

As shown in the CSM, the source of the soil contaminants present at the Small Arms Ranges is the historical release of contaminants to soil. Contaminants such as lead and explosive residues released at the sites through firing range activities and the sources of these contaminants are discussed below.

Lead

Variable concentrations of lead are known to exist at Camp Bonneville within the surface and near-surface soils at firing ranges. The source of this lead is bullets from the firing of small arms, assault weapons, artillery, and field and air defense artillery. Most of the lead bullet mass deposited in the impact area is in the form of intact bullets or large fragments; however small fragments are also present. The majority of lead bullets are likely to have impacted range berms; however, lead could be present between the firing line and the range berms. Over time elemental lead will corrode and form oxidized products consisting primarily of lead hydroxide and lead carbonates

(ITRC 2003). Due to the low mobility of lead in soil, the majority of the lead contamination is expected to have remained near the surface of the soil. The major risk posed by any metal residues arises from direct contact and ingestion of surface soil.

Explosives

The concentrations of explosive residues in the soil are expected to vary extensively throughout the Small Arms Ranges, but are most likely to be found (if detectable) in the muzzle blast area. Explosives are used as the propellant for shooting munitions forward. Propellants consist primarily of nitroglycerine and nitrocellulose. The source of the explosives is residue from barrel emissions during live fire of small arms, assault weapons, artillery, and field and air defense artillery. Explosives have a greater mobility in soils than lead.

2.7 Regulatory Classifications

Camp Bonneville and the Small Arms Ranges are located in air quality maintenance areas for ozone and carbon monoxide. As described in **Section 2.3**, hazardous substances present at the site are not volatile and generally not being released to the atmosphere, and there are currently no regulatory issues related to air quality. It is possible that future activities at the site could involve remedial actions that have the potential to emit hazardous substances to the air (e.g., dust from soil removal activities). Such activities would be regulated by the Clean Air Act and may require a permit.

The creeks and tributaries at Camp Bonneville are classed as Class A water bodies under WAC 173-201A-120 (6). These include Lacamas Creek, Buck Creek, David Creek, and tributary streams. Water quality of this class is designated as “excellent” and shall meet or exceed the requirements for all or substantially all uses. Class A water bodies must support a variety of uses, including fish and shellfish migration, rearing, spawning, and harvesting; recreation; and commerce and navigation. Cleanup standards developed for the Small Arms Ranges would be based on protecting water quality and supporting these uses.

Groundwater at the site is used to provide service to the two cantonment areas. There are two well sites, two reservoirs, and two independent water systems serving Camp Killpack and Camp Bonneville cantonment. The water quality from both of these systems is regulated under the local health department requirements. Groundwater investigations have been conducted at Camp Bonneville and are results of these investigations are being reported in other investigative reports.

3.0 STUDY AREA INVESTIGATIONS

This section describes the specific field activities undertaken during RI activities, and presents the results of the investigations at the Small Arms Ranges. The RI activities described below include the soil sampling conducted at the Small Arms Ranges in **Section 3.1**. **Section 3.2** describes the analyses and analytical methods for soil samples collected during the RI. The analytical results are presented in **Section 3.3** and a summary of the nature and extent of contamination is presented in **Section 3.4**.

Sampling was conducted by Atlanta Environmental Management, Inc. (AEM) during February and March 2003. Sampling and analyses were conducted in accordance with the approved Sampling and Analysis Plan and Quality Assurance Project Plan (AEM 2003a). Site activities were conducted in accordance with the Site Safety and Health Plan (AEM 2003a). There were minor sample location adjustments due to natural barriers such as streams, standing water, and boulders as described in **Appendix A**. Following is a summary of the RI sampling conducted. A detailed description of the RI sampling locations, methods, and procedures is presented in the Site Investigation Report (AEM 2003b) located in **Appendix A**.

3.1 Investigation at Small Arms Ranges

The RI at the Small Arms Ranges was designed to evaluate the potential for soil contamination from the firing lines of the ranges to the berms and/or potential impact areas. Previous investigations at other ranges have detected lead and explosives in the range soils. The soils at 17 Small Arms Ranges (see **Figures 5** through **21**) were sampled to identify and evaluate the presence of COPCs. The following section describes the sampling conducted at the 17 firing ranges (**Section 3.1.1**), the muzzle blast zones (**Section 3.1.2**), and the background soil sampling (**Section 3.1.3**).

3.1.1 Sampling of Firing Ranges

Soil samples were collected from half-acre grids across all the Small Arms Ranges (307 half-acre plots were sampled). All range samples were analyzed for lead. Areas excluded from this soil sampling program were range berms and backstops where bullets have accumulated. These excluded areas are being addressed separately by investigations and/or removal actions.

Characterization of each of the 307 half-acre grid in the firing ranges consisted of five grab soil samples collected from 0 – 6 inches in depth from each grid. The samples were screened to remove all clasts larger than 2 mm. The first sample was collected near the center of the sample grid. The remaining four grab samples were each collected at 40 feet from the center sample in each of the four compass directions from the center. Some sample grids were not square due to the proposed removal of target berms and backstops. In those cases, the distance to samples from the center of the grid varied.

The mapped locations and latitude/longitude for the center point of each of the half-acre grids within the firing ranges are included in **Appendix A**. The number of half-acre plots sampled, the number of muzzle blast zones sampled, and the QA/QC samples collected at each of the 17 locations are detailed in Table 3-1.

Table 3-1. Number of Samples Collected at Small Arms Ranges

Small Arms Range	Number of Half-Acre Grids Sampled	Number of Samples from each Range	Number of Muzzle Blast Zones Samples	QA/QC Samples (duplicates)	Total Number of Samples
Close Combat Range	24	120	-	11	131
25 Meter M60 Range/Pistol Range	4	20	6	1	27
Sub Machine Gun Range	7	35	-	3	38
TF Range	8	40	2	4	46
Rifle Ranges 1 & 2	32	160	7	14	181
Field Fire Rifle Ranges 1 & 2	22	110	2	10	122
Infiltration Course North	4	20	2	2	24
Field Firing Range & Pistol Range	14	70	6	16	92
Undocumented Pistol Range	1	5	5	0	10
1,000 Foot Range, Machine Gun & Moving Target Range	30	150	-	15	165
Combat Pistol Range	17	85	6	9	100
Machine Gun Range North	33	165	-	16	181
Machine Gun Range South	26	130	-	13	143
M31 Sub-Caliber Ranges 1 & 2	25	125	6	12	143
25 Meter and Machine Gun Range	13	65	10	7	82
Infiltration Course South	7	35	14	4	53
25 M Record Fire Field/Field Firing Range	40	200	2	20	222
Total	**307**	**1,535**	**68**	**157**	**1,760**

Small Arms Ranges investigated are presented in Table 3-1. At the 17 ranges, a total of 1,535 soil samples were collected and analyzed for lead. **Figures 5** through **19** show the grid locations sampled at each of the 17 firing ranges.

3.1.2 Sampling of Muzzle Blast Zones

For ranges where the firing line has been determined, a muzzle blast zone has been designated as a strip in front of and parallel to the firing line. Samples were collected along that strip at approximately 30-foot intervals within 10 feet of the firing line. A point at the end of the firing line was designated and sampled. A line was then run parallel to the firing line from that first sample and subsequent samples taken every 30 feet. The muzzle blast samples were grab samples of soil from 0 – 6 inches in depth. Samples collected in muzzle blast zones were analyzed in the laboratory for explosives (EPA Method 8330 Modified). The mapped locations and latitude/longitude for the sampling points in each of the muzzle blast zone sampling locations are included in **Appendix A**. The muzzle blast zone samples included collection of 68 grab samples over 12 ranges where the firing line was known. The ranges and number of number of muzzle blast zones sampled are presented in **Table 3-1**. Locations of the muzzle blast zone samples are shown on **Figures 5** through **19** for those ranges where the firing line could be determined.

3.1.3 Background Soil Samples

Twenty (20) soil samples were collected to identify the background levels of lead in soil in the upper soil zone. The number of background samples (20) was selected as a reasonable number to provide an estimate of the range and distribution of lead in background soils. The soil samples collected from the 20 background locations were analyzed for lead using EPA Method 6010. Background soil sample locations were selected based on the following criteria:

- Within the boundary of Camp Bonneville;
- Within similar geology/geomorphology as range grid samples;
- Outside and upslope of the known boundaries of Small Arms Ranges;
- Upslope of known firing line areas; and
- Outside of known demolition, artillery firing points, and artillery impact areas.

Locations of the 20 background samples are shown on **Figure 20**.

3.2 Sample Analyses

Soil samples collected from all Small Arms Range grid locations were analyzed for lead. Results of the lead analyses are reported on a dry-weight basis. At 10 Small Arms Range grid locations, 10 samples were randomly selected from the range soils and analyzed for 9 Priority Pollutant Metals.

Samples collected from the Muzzle Blast Zones were analyzed for explosive residues, including

picric acid and pentaerythritol tetranitrate (PETN).

Background soil samples were analyzed for lead and two randomly selected background samples were also analyzed for Priority Pollutant Metals.

The analyses conducted on soil samples collected during the RI, along with the analytical methods, are summarized in **Table 3-2**. Quality Assurance and Quality Control for all analyses are described in **Section 4.0** of **Appendix A**.

Table 3-2 Summary of Sample Analyses

Investigation Area and Sample Types and (Number of Samples)	Laboratory Analysis	Analytical Method (SW 846 or EPA approved)
FIRING RANGES		
Grid Soil Samples (1535)	Lead	EPA Method 7420 (dry-weight basis)
Grid Soil Samples (10)	Metals[a]	EPA Method 6010B
MUZZLE BLAST ZONES		
Soil Samples (68)	Explosives[b] (with Pitric acid and PETN[c])	EPA Method 8330 Modified
BACKGROUND		
Background Soil (20)	Lead	EPA Method 7420 (dry-weight basis)
Background Soil (2)	Metals	EPA Method 6010B

Notes:
[a] Metal analyses included Priority Pollutant Metals: antimony, arsenic, barium, cadmium, chromium, copper, lead, nickel, and zinc.
[b] Explosives included: HMX, RDX, 1,3,5-TNB, 1,3-DNB, Tetryl, NB, 2,4,6-TNT, 4-Am- DNT, 2-Am-DNT, 2,4-DNT, 2,6-DNT, 2-NT, 3-NT, 4-NT, Picric Acid, and PETN.
[c] PETN = pentaerythritol tetranitrate

3.3 Analytical Results

The laboratory analytical results for analyses conducted on samples collected during the RI are presented in this section. The results are summarized for each of the 17 firing range areas, the 12 muzzle blast zones, and the background samples. The following summary of analytical results

presents sample results that exceed screening levels, that is, 50 mg/kg lead in soils and explosive residues that exceed the EPA Region 9 Preliminary Remediation Goals (PRGs). Complete analytical results, including all sample results below screening levels and all sample and grid locations, are presented in **Appendix A**. Quality Assurance and Quality Control for all analyses are described in **Section 4.0** of **Appendix A**.

3.3.1 Small Arms Ranges

Tables A-1 through **A-17** (**Appendix A**) present the lead results for all samples collected at the Small Arms Range grid locations. A total of 1,535 samples, not including duplicate samples, were collected and analyzed for lead from 307 grids sampled. Five individual grab samples were collected from each grid.

The number of samples collected at each firing range and the number of samples with lead concentrations exceeding lead screening levels are summarized in **Table 3-3**. The lead concentrations are compared to ecological indicator concentrations and MTCA Method A cleanup levels. These concentrations are used for comparison only and are not intended to be the final cleanup levels or goals for the affected range areas. The concentrations are defined as follows:

- 50 mg/kg - From MTCA Table 749-3, Ecological Soil Concentrations (mg/kg) for Protection of Terrestrial Plants and Animals, for protection of plants. Not a cleanup level
- 118 mg/kg - From MTCA Table 749-3, Ecological Soil Concentrations (mg/kg) for Protection of Terrestrial Plants and Animals, for protection of wildlife. Not a cleanup level.
- 250 mg/kg - From MTCA Table 740-1, Method A Soil Cleanup Levels for Unrestricted Land Uses. Lead cleanup level based on preventing unacceptable blood lead levels.
- 500 mg/kg – Maximum lead concentration allowed for sites cleaned up to Unrestricted Land Use standards.
- 1,000 mg/kg - From MTCA Table 745-1, Method A Soil Cleanup Levels for Industrial Properties. Cleanup level based on direct contact.

Concentrations of lead in Small Arms Range grid samples exceeded the lowest screening level (50 mg/kg) at 14 of the 17 ranges. Approximately 12 percent of the samples collected at the 17 firing ranges had concentrations above 50 mg/kg. The number of samples with lead concentrations exceeding 118 mg/kg was 78, or approximately 5 percent. The percent of samples exceeding 250 mg/kg, 500 mg/kg, and 1,000 mg/kg were approximately 2.5 percent, 1.7 percent, and 1 percent, respectively (**see Table 3-3**).

Ten samples from random range grid locations were also analyzed for metals. The results of these analyses are presented on Appendix A, **Table A-19**. No concentrations of metals were detected in the ten range grid samples at concentrations above MTCA Method A for unrestricted land use, or if no MTCA criteria were available, the EPA Region 9 Preliminary Remediation Goals (PRGs). The reporting limit on several samples was above the MTCA Method A cleanup level for arsenic. In addition, one sample from a muzzle blast zone was inadvertently analyzed by the laboratory for metals. The arsenic concentration in this sample was 22.9 mg/kg, slightly above the Method A cleanup level of 20 mg/kg. All arsenic concentrations were significantly below the natural background levels in Clark County based on EPA Method 6010, Inductively Coupled Plasma (ICP) Atomic Emission Spectroscopy (Ecology 1994).

3.3.2 Muzzle Blast Zones

The 12 ranges where the firing line could be determined were sampled along the muzzle blast zone. The ranges sampled and numbers of muzzle blast zone samples collected are summarized on **Table 3-1**. As presented in **Table 3-2**, samples collected from the Muzzle Blast Zones were analyzed for explosive residues, including picric acid and pentaerythritol tetranitrate (PETN). Results of the analyses are presented in **Appendix A** (**Tables A-23** through **A-34**) for the 12 ranges sampled.

Table 3-3 Number of Samples Exceeding Lead Screening Levels

Small Arms Range	Number of Samples from each Range	Number of Samples > 50 mg/kg	Number of Samples > 118 mg/kg	Number of Samples > 250 mg/kg	Number of Samples > 500 mg/kg	Number of Samples > 1,000 mg/kg
Close Combat Range	120	1	0	0	0	0
25 Meter M60 Range/Pistol Range	20	5	2	0	0	0
Sub Machine Gun Range	35	0	0	0	0	0
TF Range	40	0	0	0	0	0
Rifle Ranges 1 & 2	160	50	18	9	6	5
Field Fire Rifle Ranges 1 & 2	110	14	2	1	1	1
Infiltration Course North	20	0	0	0	0	0
Field Firing Ranges 1 & 2 & Pistol Range	70	10	8	4	2	1
Undocumented Pistol Range	5	2	1	0	0	0
1,000 Foot Range, Machine Gun & Moving Target Range	150	39	24	13	8	6
Combat Pistol Range	85	6	2	1	1	0
Machine Gun Range North	165	11	1	0	0	0
Machine Gun Range South	130	2	2	1	0	0
M31 Sub-Caliber Ranges 1 & 2	125	1	0	0	0	0
25 Meter and Machine Gun Range	65	20	11	7	6	4
Infiltration Course South	35	2	1	0	0	0
25 M Record Fire Field/Field Firing Range	200	16	6	3	2	1
Total	**1,535**	**179**	**78**	**39**	**26**	**18**
Percent of Samples Above Screening Level		**12%**	**5%**	**2.5%**	**1.7%**	**1%**

When compared to the Region 9 PRGs for explosive residues (no MTCA criteria are established), none of the 68 samples from the muzzle blast zones exceeded the screening criteria. The explosive residue 2,4-dinitrotoluene (2,4-DNT) was detected in 8 of 10 muzzle blast zone samples collected from the 25-Meter and Machine Gun Range. Concentrations of 2,4-DNT detected ranged from 4.9 to 20 mg/kg, significantly below the PRG value of 120 mg/kg for residential soil.

Explosive residue concentrations in all other samples collected from the muzzle blast zones were below method reporting limits. Therefore, there were no explosive residues concentrations detected from any of the 12 muzzle blast zones sampled that exceeded any PRG.

One sample from the muzzle blast zones at Rifle Range 1 and 2 was inadvertently analyzed for metals. The only metal detected at a concentration above MTCA Method A for unrestricted land use and/or Region 9 PRGs was arsenic at 22.9 mg/kg. This concentration is slightly above the Method A cleanup level of 20 mg/kg. As discussed in **Section 3.2.1**, this arsenic concentration is within the natural occurring background concentrations in Clark County based on ICP analytical methods.

3.3.3 Background Samples

Twenty background samples were collected and analyzed for lead (see **Table A-18**). Concentrations of lead detected ranged from 9.7 mg/kg to 80.8 mg/kg. The average lead concentration detected was 24.3 mg/kg, or below the most stringent MTCA or PRG value for lead. The 95th percentile upper confidence limit (UCL) on the mean lead background concentration is 33.6 mg/kg.

Two background samples were also analyzed for Priority Pollutant metals. These results are presented in **Appendix A** (**Table A-19**). Metals detected were within normal background ranges.

3.4 Summary of the Nature and Extent of Contamination

This section discusses the nature and extent of soil contamination at the Small Arms Ranges. The contaminants detected above screening levels and MTCA cleanup levels are described along with the location and estimated volume of impacted soil.

3.4.1 Small Arms Ranges

The majority of samples from the Small Arms Ranges with lead concentrations exceeding screening levels were clustered in specific sampling grids. Of the 307 grids sampled, only 75 grids contained samples with lead concentrations above 50 mg/kg. Grids with lead concentrations exceeding 118 mg/kg, 250 mg/kg, 500 mg/kg, and 1,000 mg/kg, were 38, 19, 14, and 10 grids, respectively (**see Table 3-4**).

Of the 307 half-acre grids sampled, only 10 grids, or 3 percent, had lead concentrations exceeding 1,000 mg/kg. The number of grids with samples exceeding 500 mg/kg lead was 14, or approximately 5 percent. Grids with samples exceeding 250 mg/kg totaled 19, or approximately 6 percent of the total grids sampled. A summary of the grid locations and number of grids with lead concentrations exceeding screening values is presented in

Table 3-4. Tables with results from all RI sampling are presented in **Appendix A** of the attached Site Investigation Report. Figures illustrating results from all RI sampling are also presented in **Appendix B** of the Site Investigation Report.

Table 3-4 Number of Grids with Samples Exceeding Screening Levels

Small Arms Range Designation	Number of Grids with Lead Concentrations				
	> 50 mg/kg	> 118 mg/kg	> 250 mg/kg	> 500 mg/kg	> 1,000 mg/kg
Close Combat Range	1	0	0	0	0
25 Meter M60 /Pistol Range	3	1	0	0	0
Sub Machine Gun Range	0	0	0	0	0
TF Range	0	0	0	0	0
Rifle Range 1 & 2	16	8	4	3	2
Field Fire Rifle Ranges 1 & 2	10	2	1	1	1
Infiltration Course North	0	0	0	0	0
Field Firing Range &Pistol	4	3	2	1	1
Undocumented Pistol Range	1	1	0	0	0
1,000 ft Range, 1,000 Machine	11	8	5	3	3
Combat Pistol Range	4	2	1	1	0
Machine Gun Range North	6	1	0	0	0
Machine Gun Range South	2	2	1	0	0
M31 Sub-Caliber Ranges 1 & 2	1	0	0	0	0
25 m & Machine Gun Range	7	6	3	3	2
Infiltration Course South	2	1	0	0	0
25M Record Fire Field Range/Field Fire Range	7	3	2	2	1
Total Number of Grids	**75**	**38**	**19**	**14**	**10**
Percent of Grids with Samples Above Screening Levels	**24%**	**12%**	**6%**	**5%**	**3%**

3.4.1.1 Areas and Volumes at Small Arms Ranges

The areas and volumes of lead contaminated soils at the Small Arms Ranges was calculated based on the locations of the samples containing lead at concentrations

exceeding MTCA ecological indicator and cleanup levels. A summary of the areas of ranges affected is presented in **Table 3-5**. Estimated volumes of affected soils are presented in **Table 3-6**.

The areas and volumes of affected soil were calculated based on removing an area 40 by 40 feet by 6 inches deep at any "hot" soil location within a grid. Two 40 by 40 feet areas would be removed if two "hot" soil samples were located in the same grid. If three or more "hot" soils were located within a single grid, the entire grid would be removed.

Table 3-5 Areas of Impacted Grids

Small Arms Range Designation	Area of Impacted Grids (square yards)				
	> 50 mg/kg	>118 mg/kg	> 250 mg/kg	> 500 mg/kg	> 1,000 mg/kg
Close Combat Range	178	0	0	0	0
25 Meter M60 /Pistol Range	2,910	312	0	0	0
Sub Machine Gun Range	0	0	0	0	0
TF Range	0	0	0	0	0
Rifle Range 1 & 2	18,676	10,214	3,144	2,776	2,598
Field Fire Rifle Ranges 1 & 2	2,225	356	180	178	178
Infiltration Course North	0	0	0	0	0
Field Firing Range & Pistol	5,196	2,760	2,604	356	178
Undocumented Pistol Range	312	178	0	0	0
1,000 ft Range, 1,000 Machine	19,850	12,768	7,632	5,196	5,196
Combat Pistol Range	2,954	534	180	178	0
Machine Gun Range North	1,603	178	0	0	0
Machine Gun Range South	356	356	180	0	0
M31 Sub-Caliber Ranges 1 & 2	178	0	0	0	0
25 Meter Machine Gun Range	12,456	5,552	2,784	2,776	445
Infiltration Course South	356	178	0	0	0
25M Record Fire Field Range	7,972	5,018	540	356	178
Total (square yards)	**75,222**	**38,404**	**17,244**	**11,816**	**8,773**

As summarized in **Table 3-5**, the areas of affected soil above MTCA cleanup levels ranges from approximately 9,000 square yards (based on 1,000 mg/kg cleanup level) to approximately 17,000 square yards (based on 250 mg/kg cleanup level). The number of impacted areas varies from 6 to 8 depending on the cleanup levels (250 mg/kg – 1,000 mg/kg).

Table 3-6 Volume of Impacted Grids

Small Arms Range Designation	Volume of Impacted Grids (cubic yards)				
	> 50mg/kg	> 118 mg/kg	> 250 mg/kg	> 500 mg/kg	> 1,000 mg/kg
Close Combat Range	30	0	0	0	0
25 Meter M60 /Pistol Range	486	52	0	0	0
Sub Machine Gun Range	0	0	0	0	0
TF Range	0	0	0	0	0
Rifle Range 1 & 2	3,119	1,706	524	464	434
Field Fire Rifle Ranges 1 & 2	372	59	30	30	30
Infiltration Course North	0	0	0	0	0
Field Firing Ranges 1&2 &Pistol	868	461	434	59	30
Undocumented Pistol Range	52	30	0	0	0
1,000 ft Range, 1,000 Machine	3,315	2,132	1,272	868	868
Combat Pistol Range	493	89	30	30	0
Machine Gun Range North	268	30	0	0	0
Machine Gun Range South	59	59	30	0	0
M31 Sub-Caliber Ranges 1 & 2	30	0	0	0	0
25 m & Machine Gun Range	2,080	927	464	464	74
Infiltration Course South	59	30	0	0	0
25M Record Fire Field Range	1,331	838	90	59	30
Total (cubic yards)	**12,562**	**6,413**	**2,874**	**1,974**	**1,466**

Nine of the 17 Small Arms Ranges do not have any grid sample concentrations that exceed 250 mg/kg lead, the unrestricted land use cleanup level. Only 6 of the 17 ranges exceed the industrial lead cleanup level of 1,000 mg/kg. Therefore, the estimated volumes of affected soil above MTCA cleanup levels range from 2,874 cubic yards (based on 250 mg/kg cleanup level) to 1,466 cubic yards (based on 1,000 mg/kg lead cleanup level).

No other metals were a concern at the 17 Small Arms Ranges based on the 10 range samples analyzed for priority pollutant metals. All metals detected in these samples were detected at concentrations below MTCA Method A unrestricted land use cleanup levels. Therefore, the only contaminant of concern is the lead in soil at the Small Arms Ranges.

3.4.2 Muzzle Blast Zones

There were no concentrations of explosive residues detected in the 68 muzzle blast zone samples at concentrations above the conservative PRG screening levels. The one detection of arsenic in the muzzle blast zone was detected at near the reporting limit and is not considered significant. As discussed in **Section 3.3.2**, there are no contaminants of concern in the muzzle blast zones of the ranges where firing points were identified. Therefore, there are no contaminants of concern within the muzzle blast zones requiring further action.

4.0 RISKS TO HUMAN HEALTH AND ECOLOGICAL RECEPTORS

Selecting a cleanup action requires a determination that each of the requirements specified in WAC 173-340-360 is met, including the requirement that the cleanup action is protective of human health and the environment [(WAC 173-340-357(2)]. Cleaning up a site to MTCA Method A residential land use cleanup standards will provide protection of human health because they provide the most protective cleanup levels. A quantitative human health risk assessment is not required if a site is cleaned up to residential land use standards. The cleanup action proposed for the Small Arms Ranges will meet these criteria, as described in **Section 5.0**. Therefore, the cleanup action proposed for the ranges will be protective of human health if the ranges are cleaned up to residential use standards.

WAC 173-340-7490 specifies the terrestrial ecological evaluation procedures for sites where a release of a hazardous substance has occurred. Because of the prime ecological habitat at Camp Bonneville, the Small Arms Ranges do not qualify for exclusion or a simplified terrestrial ecological evaluation (WAC 173-340-7490). Therefore, a site-specific terrestrial ecological evaluation is required under WAC 173-340-7493.

The first step in conducting a terrestrial ecological evaluation is completing the "problem formulation step". The first problem formulation step is to determine the chemicals of ecological concern at the affected areas. This evaluation may eliminate hazardous substances from further consideration where the maximum or the upper ninety-five percent confidence limit (UCL) soil concentration found at the site does not exceed ecological indicator concentrations described in MTCA Table 749-3. The table specifies ecological indicator soil concentrations for lead as follows: Plants – 50 mg/kg; Soil Biota – 500 mg/kg, and Wildlife – 118 mg/kg.

MTCA specifies that chemicals of concern used in ecological evaluations may be eliminated from further consideration if "the maximum or the upper ninety-five percent confidence limit soil concentration found at the site does not exceed ecological indicator concentrations described in Table 749-3" [WAC 173-340-7493 (2)(a)(i)]. After the proposed cleanup action described later in this document is conducted, the 17 Small Arms Ranges will have a residual lead concentration of less than 30 mg/kg based on the average 95th percentile UCL of the mean. This UCL is based on grouping the 17 ranges into four data sets for calculating UCLs because the maximum number of data points for "MTCAstat97" is 500. Following remedial action, it is estimated that 2 of the 17 ranges will have range-specific UCLs that exceed the most conservative ecological indicator for plants, 50 mg/kg. The 95th percentile UCL on the mean at one of these ranges, the Undocumented Pistol Range, is skewed high because only five samples were collected at that range. The 25 Meter M60 Range is also skewed high because the data set is comprised of only 20 samples. The other range, the 25 meter and Machine Gun Range, will have a UCL of 54 mg/kg, slightly above the ecological indicator soil concentration for plants of 50 mg/kg.

As stated previously, spent lead bullets will tend to oxidize primarily into the nearly insoluble lead hydroxide and lead carbonate (ITRC 2003). In addition, the phytotoxicity of lead is relatively low compared with other trace elements (Miles 1972). It should also be noted that the MTCA ecological

indicator concentrations for plants are based on benchmark values from various studies compiled by Oak Ridge National Laboratory (ORNL) [ORNL 1997]. The vast majority of the lead studies cited used significantly more soluble lead compounds (lead chloride) than the likely form of nearly insoluble lead (lead hydroxide and lead carbonates) at the Camp Bonneville ranges. Therefore, it is very likely that the MTCA ecological indication concentration for plants (50 mg/kg) from lead in soil may not be appropriate for the forms of lead in soils at Camp Bonneville ranges.

A site inspection of the most contaminated grids at the ranges was conducted on June 5, 2003 by Project Performance Corporation. No visual evidence of stressed vegetation was noted. The plant species observed and the health of the plants appeared the same on contaminated and background locations. Therefore, the residual lead concentrations after remediation of the ranges will be insignificant to plants and other ecological receptors and lead in soil will not be considered a chemical of ecological concern.

After reviewing the above "problem formulation step", no further site-specific terrestrial ecological evaluation is necessary because the cleanup action plan proposed for protection of human health (cleanup to Method A residential land use) will eliminate any significant risks to ecological receptors. In addition, following the proposed cleanup of the lead contaminated areas at the ranges, lead will not be considered a chemical of ecological concern and no further ecological assessment is required under WAC 173-340-7493.

5.0 CLEANUP ACTION OBJECTIVES

This section presents conclusions concerning the need for and objectives of cleanup actions at the Small Arms Ranges. Based on results of RI, the following conclusions are drawn with respect to contamination at the Small Arms Ranges:

- Lead is present in surface and near-surface soil at several Small Arms Ranges at concentrations above cleanup standards.

- Natural attenuation mechanisms do not constitute an effective mechanism to reduce lead contaminant concentrations in soil to cleanup standards.

If cleanup actions were implemented, this would increase the confidence that lead concentrations in soil would be reduced and potentially impacts to deeper soils and possibly groundwater would be reduced. Based on the above conclusions, identification and evaluation of cleanup actions for specific Small Arms Ranges is appropriate.

Cleanup actions at the Small Arms Ranges would have the following objectives:

Prevent the potential exposure of contaminants in soil to human and ecological receptors at concentrations greater than cleanup standards support the proposed re-use and/or redevelopment of the site.

Potential human receptors at the Small Arms Ranges include on-site workers, visitors to the site, and adjacent residents. Potential ecological receptors include plants and wildlife that may use affected areas.

As described previously, soil cleanup standards based on MTCA Method A unrestricted residential use have been determined appropriate for the Small Arms Ranges based on the potential future land use. The ecological indicator concentrations and cleanup levels applicable to soils at the Small Arms Ranges are shown on **Table 5-1**.

MTCA requires the soil cleanup levels be based on estimates of the reasonable maximum exposure expected under both current and future site use conditions. Historically, the site was a US Army military reservation with controlled access and used for short-term, small unit training exercises. Future uses proposed for the site may include development of a regional park and environmental preservation area. The proposed future land uses may include educational activities, law enforcement training, and public recreation. The possible public uses may involve short-term camping and group use of existing or new structures for overnight programs. Based on these potential future land use, the appropriate cleanup level is the MTCA Method A Soil Cleanup Level for Unrestricted Land Use for lead. Therefore, the proposed cleanup level for lead in soil at the Small Arms Ranges is 50 mg/kg. If future land use at Camp Bonneville differs from the proposed land use, the appropriate cleanup level should be reevaluated at that time.

Table 5-1. MTCA Ecological Indicator and Cleanup Levels for Lead in Soil

	Ecological Indicator for Plants[1]	Ecological Indicator for Wildlife[2]	Unrestricted Land Use[3]	Industrial Properties[4]
Lead Concentration (mg/kg)	50	118	250	1,000

Notes:

1 From MTCA Table 749-3, Ecological Soil Concentrations (mg/kg) for Protection of Terrestrial Plants and Animals, a lead concentration of 50 mg/kg is specified for or protection of plants.

2 From MTCA Table 749-3, Ecological Soil Concentrations (mg/kg) for Protection of Terrestrial Plants and Animals, a lead concentration of 118 mg/kg is specified for protection of wildlife.

3 From MTCA Table 740-1, Method A Soil Cleanup Levels for Unrestricted Land Uses. The lead cleanup level is based on preventing unacceptable blood lead levels.

4 From MTCA Table 745-1, Method A Soil Cleanup Levels for Industrial Properties, the cleanup level is based on direct contact.

In developing Method A cleanup levels for unrestricted land use, MTCA [(WAC 173-340-740 (2)] requires that the cleanup level must be as stringent as the following:

- Concentrations in MTCA Table 740-1 and compliance with the corresponding footnotes (this table specifies a lead cleanup level of 250 mg/kg for unrestricted land use);
- Concentrations established under applicable state and federal laws;
- Concentrations that result in no significant adverse effects on the protection and propagation of terrestrial ecological receptors using the procedures specified in WAC 173-340-7490 through 7493 (tables in this section specify ecological indicator soil lead concentrations for plants, soil biota, and wildlife at 50, 500, and 118 mg/kg, respectively).
- Concentrations that are protective of groundwater [Method A cleanup levels were designed to be protective of groundwater, that is, lead concentrations in soil less than 3,000 mg/kg (Ecology 2001).

In addition, MTCA requires the following when determining compliance with cleanup levels:

- The upper one sided 95% confidence limit on the true mean soil concentration shall be less than the soil cleanup level [WAC 173-340-740(7)(d)(i)(a)];
- No single sample concentration shall be greater than two times the soil cleanup level [WAC 173-340-740(7)(e)(i)]; and
- At least 90% of the sample concentrations shall be less than the soil cleanup level [WAC 173-340-740(7)(e)(ii).

Based on these regulations, the approach for cleanup must comply with the following:

- The 95th percentile upper confidence limit (UCL) on the mean lead concentrations remaining after remediation from each small arms range must be less than 50 mg/kg;
- No lead sample concentrations after remediation can exceed 100 mg/kg; and
- At least 90% of the lead concentrations reported in confirmatory samples representing the soils remaining after remediation from each of the Small Arms Ranges must be less than 50 mg/kg.

6.0 IDENTIFICATION OF CLEANUP TECHNOLOGIES

This section identifies specific cleanup technologies that may be used to achieve the cleanup objectives and cleanup levels specified in **Section 5.0**. As noted in WAC 173-340-350(8)(b), in some cases it is necessary to perform an initial screening of alternatives to reduce the number for detailed evaluation. However, for the Small Arms Ranges, appropriate technologies can readily be identified and screening is not necessary. The following technologies have been considered for remediation of the Small Arms Ranges. The discussion for each technology contains a brief description of the technology, its expected effectiveness, and relevant operational concerns

No Action: The no action alternative assesses the consequences of leaving a site in its current state.

Institutional Controls: Institutional controls refer to a broad category of measures that can be used to limit or prevent contact with affected soils. These controls might include deed restrictions, permitting requirements, training programs, and use restrictions. Controls that may be applicable include signs, access restrictions (fences), land use restrictions, and runoff control.

Containment (Capping): Containment for soil refers to a vertical physical barrier (soil cap) intended to reduce infiltration of rainwater through contaminated soil and to restrict direct contact with the soil. Capping would involve placing clean soil cover over the contaminated soil and leaving the contaminated soil in place. An impermeable cap of asphalt, concrete, or geomembrane, also satisfies the basic requirements of physical barriers described above and would further reduce the potential for infiltration of rainwater.

Consolidation and Containment (Capping): Consolidation refers to excavation of contaminated soil above the action level and consolidating the soils into one or more on-site areas. The consolidated soils would then be contained (capped) as described above.

Excavation and Off-site Disposal or Recycling: This alternative refers to excavating soil with contaminant concentrations exceeding a specified action level and hauling the soil to an off-site facility for disposal or recycling. This alternative may also include physical sorting/screening to remove rocks and gravel and possibly larger metal fragments (lead bullets and shells). Soils would have to be tested using TCLP methods to determine if soils are characteristic hazardous wastes under RCRA and would require disposal at one or more RCRA-approved landfills.

7.0 EVALUATION AND SELECTION OF CLEANUP ACTIONS

This section identifies cleanup actions comprised of selected technologies described in Section 7.0, and presents an evaluation of these actions with respect to the selection criteria contained in WAC 173-340-360. This evaluation is designed to provide a basis from which a preferred cleanup action can be selected.

The criteria used for evaluating the alternatives included the requirements established under MTCA (WAC 173-340-360) for evaluation of remedial alternatives. The criteria include four threshold factors: protection of human health and the environment, compliance with cleanup standards, compliance with applicable state and federal laws, and provision for compliance monitoring. The other requirements for the selected alternative are: use permanent solutions to the maximum extent practicable, provide for a reasonable restoration time frame, and consider public concerns.

7.1 Identification of Cleanup Action Alternatives

Based on evaluation of the candidate technologies presented in Section 7.0, five alternative cleanup actions were identified for the Small Arms Ranges. These alternatives consist of the following:

- Alternative 1 - No Action.
- Alternative 2 - Institutional Controls.
- Alternative 3 - Containment (Capping).
- Alternative 4 - Consolidation and Containment (Capping)
- Alternative 5 - Excavation and Off-site Disposal or Recycling

7.2 Procedure for Selection of Cleanup Actions

The MTCA Rules specify the procedure to be used to select the cleanup action from the identified alternatives at WAC 173-340-360. This rule specifies Minimum Requirements for Cleanup Actions at WAC 173-340-360 (2). The Minimum Requirements are further divided into two categories, as follows:

- Threshold requirements (WAC 173-340-360 (2) (a)
  - Protection human health and the environment
  - Compliance with applicable cleanup standards
  - Compliance with applicable state and federal laws
  - Provisions for compliance monitoring

- Other requirements (WAC 173-340-360 (2) (b)
  - Use permanent solutions to the maximum extent practical
  - Provide for a reasonable restoration time frame
  - Consider public concerns

The MTCA Rules also set forth a specific procedure to determine whether a cleanup action uses

permanent solutions to the maximum extent possible. This procedure is found at WAC 173-340-

360 (3) and provides evaluation criteria to determine the permanence of the candidate cleanup action approaches: These seven evaluation criteria are as follows:

- Protectiveness
- Permanence
- Cost
- Effectiveness ver the long term
- Management of short-term risks
- Technical and administrative implementability
- Consideration of public concerns

It is noted that this RI/FS will be subjected to public notice and public comment procedures as specified at WAC 173-340-600. This procedure will provide a mechanism to identify and respond to public concerns that may arise which have not been identified to date for this site.

Also, it is noted that it does not appear necessary or appropriate to apply the Disproportionate Cost Analysis established at WAC 173-340-360 (e) to this RI/FS. The alternatives analysis provided below in this RI/FS does not raise the issue of disproportionate costs. Clearly, however, it is appropriate to conduct a qualitative evaluation of the permanence or the alternate remedial approaches following the procedure defined in the Rules.

The following subsections address these alternative evaluation procedures as follows:

- Section 7.3 provides a description of each alternative and discusses the evaluation of each in terms of the Threshold and Other Requirements with a general discussion of permanence.

- Section 7.4 provides a more detailed qualitative evaluation and ranking of each alternative using the Evaluation Criteria for the Permanence Requirement.

- Section 7.5 provides recommendations and conclusions.

7.3 Detailed Evaluation of Cleanup Action Alternatives

This section presents a detailed evaluation of the five cleanup action alternatives identified in Section 8.1. The following presents s description of each alternative and an evaluation of the alternative with respect to the requirements contained in WAC 173-34-360 (2) and (3).

7.3.1 Alternative 1 – No Action

Description of Alternative: The no action alternative is used to establish the risk levels and site conditions if no physical cleanup actions are implemented. Under the no action alternative, site conditions and risk levels would remain as they currently exist. No

physical changes or land use/access restrictions would be implemented that would affect activities at the site. No engineering or institutional controls would be established and no

remedial actions would be initiated to reduce hazard levels at the site. Land development, site maintenance, and site improvements would continue in accordance with prevailing practices.

Threshold Requirements:

Protection of Human Health and the Environment: Under the no action alternative, affected areas of the site would remain as they currently are with no reduction in toxicity, mobility, or volume of impacted soils. No additional protection would be afforded potential human and ecological receptors to reduce the opportunities for ingestion or dermal contact in affected areas. Without institutional controls and physical barriers or capping as safeguards against potential exposure, receptors may inadvertently face exposure to affected soil.

Compliance with Cleanup Standards: The no-action alternative will not meet MTCA cleanup standards because soils with lead concentrations above cleanup standards would remain on site.

Compliance with Applicable Laws: Implementation of this alternative would not involve compliance with laws and regulations related to wastewater discharges, air discharges, or dangerous waste management. Implementation of this alternative would result in compliance with these laws and regulations, but would not satisfy the requirements of MTCA.

Provision of Compliance Monitoring: The no-action alternative would not include compliance monitoring.

Other Requirements:

Permanent Solutions to the Maximum Extent Practicable: This cleanup action would not result in permanent reduction in the toxicity, mobility, or volume of hazardous substance at the site. Therefore, the no action alternative would not provide permanent solutions to the maximum extent practicable.

Attaining Cleanup in a Reasonable Time: The no action alternative does not attain cleanup of the site in a reasonable time. Due to the elemental nature of the contaminant, the no action alternative does not cleanup the site in a reasonable time period.

Public Concerns: Public concerns would be addressed after receipt of public comments on the proposed cleanup action. The no action alternative would not likely address the concerns of the community because no active remediation would be conducted.

7.3.2 Alternative 2 – Institutional Controls

Description of Alternative: The institutional controls alternative refers to establishing access restrictions, legal restrictions, and educational procedures and rules to reduce the potential for adverse impacts. For example, access restriction, such as fences, and education of site visitors would be implemented to limit human access to areas at the site exceeding cleanup levels. The potential exposure pathway would therefore be reduced. As with the no action alternative, this alternative would not treat or additionally contain affected soil and existing potential exposure routes for ecological receptors would remain.

This alternative would include minimum standards for fences and locating signs in affected areas to warn workers and/or visitors on site of the potential for exposure associated with contact with and/or disturbance of the soil. Other posted notices or bulletins would be located in high-visibility areas and periodic reminders would be provided to on-site workers and visitors.

Deed restrictions would be recorded to advise potential owners of the property of the hazards and use limitations associated with the specific affected areas. Grading or excavation in the affected areas would not be allowed without appropriate safety consideration. Zoning and other permit restriction would be implemented to limit site uses to avoid potential exposure. Surface water flow could transport soil in affected areas and control measures would have to be implemented to reduce the potential migration of affected soil. Periodic site inspections would be required to verify the condition of fences and signs and to evaluate the effectiveness of this alternative.

Threshold Requirements: The threshold requirements contained in WAC 173-340-360(2) consist of protection of human health and the environment, compliance with cleanup standards, compliance with applicable laws, and provision for compliance monitoring.

Protection of Human Health and the Environment: Under the institutional control alternative, affected areas of the site would remain as they currently are with no reduction in toxicity, mobility, or volume of impacted soils. Access restrictions and warning signs would reduce the potential opportunities for ingestion or dermal contact by human receptors in affected areas. Fences may limit large mammals from access to the affected areas; however, plants, birds, and small mammals would not be limited from the impacted areas.

Compliance with Cleanup Standards: The alternative will not meet MTCA cleanup standards because lead concentrations in soil above cleanup standards would be left on site.

Compliance with Applicable Laws: Implementation of this alternative would not involve compliance with laws and regulations related to wastewater discharges, air discharges, or dangerous waste management. Deed restrictions and zoning changes would have to be implemented in accordance with local, county, and state laws and regulations. Construction of fences and signs may require a permit and require construction to applicable standards.

Provision of Compliance Monitoring: The institutional controls alternative would include one of the three types of compliance monitoring, that is, conformation monitoring. Access restrictions, such as fences and signs, would be placed around the outside of affected areas and would not disturb areas of contamination above the cleanup levels. Confirmation monitoring of the condition of institutional controls would be required to confirm the condition and effectiveness of the control measures.

Other Requirements:

Permanent Solutions to the Maximum Extent Practicable: This cleanup action would not result in permanent reduction in the toxicity, mobility, or volume of hazardous substance at the site. Therefore, the institutional controls alternative would not provide permanent solutions to the maximum extent practicable. This alternative will not meet the requirements of MTCA because it relies primarily on institutional controls where it is possible to implement a more permanent cleanup action for all or a portion of the site.

Attaining Cleanup in a Reasonable Time: The institutional control alternative does not attain cleanup of the site in a reasonable time. Due to the elemental nature of the contaminant, the alternative does not cleanup the site in a reasonable time period.

Public Concerns: Public concerns would be addressed after receipt of public comments on the proposed cleanup action.

7.3.3 Alternative 3 – Containment (Capping)

Description of Alternative: The containment alternative refers to capping over areas where lead concentrations in soil exceed cleanup standards. The intent of the action would be to prevent dermal contact or ingestion of the affected soil by on-site workers and/or visitors. Depending on the material used for the cap, the action may also minimize chemical transport by rainwater infiltration. This alternative would contain the affected soil through placement of a cap over the affected areas. The cap would limit the potential exposure routes for human and ecological receptors. Some borrowing animals and plants with deep roots would remain potential receptors. Caps would be constructed of soil or more impermeable materials such as asphalt, concrete, or use of geomembranes.

This alternative would include minimum standards for construction of caps over contaminated soil. Capping would require clearing and grubbing of affected areas prior to placement of the cap. Deed restrictions would be recorded to advise potential owners of the property of the hazards and use limitations associated with the specific affected areas. Zoning and other permit restriction would be implemented to limit site uses to avoid potential exposure. Periodic site inspections would be required to verify the condition of caps and drainage features, and if required maintenance of the cap would be conducted.

Threshold Requirements:

Protection of Human Health and the Environment: Under the containment alternative, affected areas of the site would remain as they currently are with no reduction in toxicity or volume of impacted soils. The mobility of the contaminated soils would be reduced because the cap would act as a barrier for infiltration and also minimize the potential for dermal contact or ingestion.

Compliance with Cleanup Standards: The alternative may meet MTCA cleanup standards if all conditions in MTCA 340-740 (6)(f) are satisfied. Lead concentrations in soil above cleanup standards would be left on site; however, the soils would be contained to significantly reduce the potential for exposure. This alternative may not meet the requirement of being permanent to the maximum extent practicable.

Compliance with Applicable Laws: Implementation of this alternative would involve compliance with laws and regulations related to wastewater discharges, air discharges, or dangerous waste management. Deed restrictions and zoning changes would have to be implemented in accordance with local, county, and state laws and regulations.

Provision of Compliance Monitoring: The containment alternative would include protection monitoring during construction to confirm human health and the environment are adequately protected. Performance monitoring would be required during cap construction to confirm the cap meets design and construction specifications. Confirmation monitoring of the condition of the caps would be required to confirm their long-term condition and effectiveness.

Other Requirements:

Permanent Solutions to the Maximum Extent Practicable: This cleanup action would not result in permanent reduction in the toxicity or volume of hazardous substance at the site. Therefore, the containment alternative would not provide permanent solutions to the maximum extent practicable. This alternative will not meet the requirements of MTCA because it is possible to implement a more permanent cleanup action for all or a portion of the site.

Attaining Cleanup in a Reasonable Time: The containment alternative could reduce exposure to contaminated soil in a reasonable time; however, construction of a cap would not attain cleanup in a reasonable time period. The existing contamination would remain on site, but due to the elemental nature of the contaminant, the alternative does not cleanup the site in a reasonable time period.

Public Concerns: Public concerns would be addressed after receipt of public comments on the proposed cleanup action.

7.3.4 Alternative 4 – Consolidation and Containment (Capping)

Description of Alternative: The consolidation and containment alternative refers to consolidating affected soils in one or more areas on site and then constructing a cap over the contaminated soil. The intent of the action would be to prevent dermal contact or ingestion of the affected soil by on-site workers and/or visitors. Contaminated soils would be excavated and hauled to a suitable on-site location, compacted, and capped. Depending on the material used for the cap, the action may also minimize chemical transport by rainwater infiltration. This alternative would contain the affected soil through placement of a cap over the affected areas. The cap would limit the potential exposure routes for human and ecological receptors. Some borrowing animals and plants with deep roots would remain potential receptors. Caps would be constructed of soil or more impermeable materials such as asphalt, concrete, or use of geomembranes.

This alternative would include minimum standards for construction of caps over contaminated soil. Containment and capping would require clearing and grubbing of affected areas prior to excavation and consolidation of the contaminated soils. Deed restrictions would be recorded to advise potential owners of the property of the hazards and use limitations associated with the specific affected areas. Zoning and other permit restriction would be implemented to limit site uses to avoid potential exposure. Periodic site inspections would be required to verify the condition of caps and drainage features, and if required maintenance of the cap would be conducted.

Threshold Requirements:

Protection of Human Health and the Environment: Under the containment and capping alternative, affected areas of the site would remain as they currently are with no reduction in toxicity or volume of impacted soils. The mobility of the contaminated soils would be reduced because the cap would act as a barrier for infiltration and also minimize the potential for dermal contact or ingestion.

Compliance with Cleanup Standards: The alternative may meet MTCA cleanup standards if all conditions in MTCA 340-740 (6)(f) are satisfied. Lead concentrations in soil above cleanup standards would be left on site; however, the

soils would be contained to significantly reduce the potential for exposure. This alternative may not meet the requirement of being permanent to the maximum extent practicable.

Compliance with Applicable Laws: Implementation of this alternative would involve compliance with laws and regulations related to wastewater discharges, air discharges, or dangerous waste management. Deed restrictions and zoning changes would have to be implemented in accordance with local, county, and state laws and regulations.

Provision of Compliance Monitoring: The consolidation and containment alternative would include protection monitoring during construction to confirm human health and the environment are adequately protected. Performance monitoring would be required during cap construction to confirm the cap meets design and construction specifications. In addition, performance monitoring would be conducted at areas where soil was excavated to confirm soils remaining (not consolidated) meet cleanup standards. Confirmation monitoring of the condition of the caps would be required to confirm the long-term condition and effectiveness of the caps.

Other Requirements:

Permanent Solutions to the Maximum Extent Practicable: This cleanup action would not result in permanent reduction in the toxicity or volume of hazardous substance at the site. Therefore, the consolidation and containment alternative would not provide permanent solutions to the maximum extent practicable. This alternative will not meet the requirements of MTCA because it is possible to implement a more permanent cleanup action for all or a portion of the site.

Attaining Cleanup in a Reasonable Time: The consolidation and containment alternative could reduce exposure to contaminated soil in a reasonable time; however, construction of a cap would not attain cleanup in a reasonable time period. The existing contamination would be consolidated and remain on site, but due to the elemental nature of the contaminant, the alternative does not cleanup the site in a reasonable time period.

Public Concerns: Public concerns would be addressed after receipt of public comments on the proposed cleanup action.

7.3.5 Alternative 5 – Excavation and Off-Site Disposal or Recycling

Description of Alternative: The excavation and off-site disposal or recycling alternative includes excavation of all soils above cleanup standards and disposing or recycling of the

soils off site. The intent of the action would be to eliminate the potential for dermal contact or ingestion of the affected soil by on-site workers and/or visitors and to eliminate the potential exposure to ecological receptors. Contaminated soils would be excavated, mechanically screened to remove bullets, and soils above cleanup standards would be hauled off site for disposal or recycling.

Excavated soils from the ranges would be screened using vibrating screens to remove metal bullets, metal fragments, brass casings, rocks, and organic matter. The screened soils would be analyzed for lead concentrations and stockpiled on site. Screened soil will be disposed and/or recycled in accordance with legal requirements on the basis of the characterization results. The Army is evaluating recycling of the soil at other Army ranges and/or as using the soil in asphalt paving material. To the extent possible, recycling of non-hazardous soil would be conducted. All metal collected during soil sieving operations would be hauled off site for metal recycling. If recycling of lead and other metal fragments are not cost effective, the material would be sampled and profiled for proper disposal at an approved landfill.

This alternative would include minimum standards for excavation, screening, stockpiling, transporting, and disposal of contaminated soil with concentrations exceeding the cleanup standard. This alternative would require clearing and grubbing of affected areas prior to excavation. Screened soils would be sampled and analyzed to determine the appropriate disposition of the soil (hazardous or non-hazardous). Soils below cleanup standards would remain on site and be used as fill material in areas where excavations were conducted.

Threshold Requirements:

Protection of Human Health and the Environment: Under the excavation and off-site disposal or recycling alternative, affected areas of the site would be removed from the site. This cleanup action would result in permanent reduction in the toxicity, mobility, and volume of hazardous substance at the site. To the extent practicable, contaminated soil and lead removed from soil would be recycled. If excavated soils were determined to be hazardous, the soil would be stabilized prior to disposal in an RCRA approved landfill. Therefore, the excavation and off-site disposal or recycling alternative would provide the most permanent solution to the maximum extent practicable.

Compliance with Cleanup Standards: The alternative would meet MTCA cleanup standards because lead concentrations in soil above cleanup standards would be removed from the site.

Compliance with Applicable Laws: Implementation of this alternative would involve compliance with laws and regulations related to wastewater discharges, air discharges, or dangerous waste management. Lead screened from site soils is classified as scrap metal and is not regulated as solid waste or as hazardous waste when recycled. Under 40 CFR 261.6(a)(3)(ii), recycled scrap metal is classified

as a recyclable material that is not subject to the requirements for generators, transporters, and storage facilities of hazardous wastes. Therefore, the lead reclaimed from the range soils does not need to be regulated or manifested as a hazardous waste during generation or transport to a recycling facility. Under current regulations, soils that are recycled are exempt from RCRA regulations if the resulting product is for use by the general public, contains recyclable materials that have undergone a chemical reaction so as to become inseparable by physical means, and meets Land Disposal Restriction treatment standards [40 CFR 266.20 (b)].

Provision of Compliance Monitoring: The excavation and off-site disposal or recycling alternative would include protection monitoring during construction to confirm human health and the environment are adequately protected. Performance monitoring would be required during excavation to confirm soils remaining meet cleanup standards. Confirmation monitoring would be combined with performance monitoring to confirm the effectiveness of the removal action.

Other Requirements:

Permanent Solutions to the Maximum Extent Practicable: This cleanup action would result in permanent reduction in the toxicity, mobility, and volume of hazardous substance at the site. Therefore, the alternative would provide permanent solutions to the maximum extent practicable. This alternative meets the requirements of MTCA because it implements a more permanent cleanup action for all or a portion of the site.

Attaining Cleanup in a Reasonable Time: The alternative could attain cleanup standards in a reasonable time period. Implementation of the alternative would be most successful if the excavated and screened soil were dry so that mechanical screens do not become clogged with wet soil. Therefore, the alternative may be limited to the summer season, but still could be attained in a reasonable time.

Public Concerns: Public concerns would be addressed after receipt of public comments on the proposed cleanup action.

7.4 Permanence Evaluation

The Permanence evaluation specifies consideration and comparison of each candidate alternative using seven criteria specified in WAC 173-340-360 (3) (f). The following discussion provides these comparisons in narrative format.

- Protectiveness: Alternate 5 is clearly superior in protectiveness of both human health, the environment, and attainment of cleanup standards as this alternate involves the recycling of recoverable lead, the removal, treatment and proper disposal of any hazardous materials, and the removal to an appropriate offsite facility of soils exceeding the cleanup

standard for lead. Alternative 4 is less protective in that it involves consolidating the materials to one on-site location and providing a protective cover. Alternative 3 is still less protective in that the materials would be left in place with covers installed at each material location. Alternatives 1 and 2 are least protective in that they do not involve any physical action to remove, consolidate, treat, or cover the lead-containing soils.

- Permanence: Alternate 5 is clearly superior in permanence as this alternate involves the permanent actions in the form of recycling of recoverable lead, treatment and proper disposal of hazardous materials, and removal of soils exceeding the cleanup standard for lead. Alternative 3 and 4 are less permanent in that both involve maintenance of the protective cover(s). Alternatives 1 and 2 are least permanent in that they do not involve any physical action to remove, consolidate, treat, or cover the lead-containing soils.

- Cost: The five alternatives are ranked in numerical order from least to highest cost. However, Alternatives 3, 4, and 5 would be relatively comparable in overall cost when the long-term costs associated with cap maintenance are considered. As noted above, this RI/FS does not advance a disproportionate cost analysis.

- Effectiveness Over the Long Term: Alternative 5 is clearly superior over the long term since this is the only alternative that involves removal of soils with lead concentrations exceeding the cleanup standards. The long-term effectiveness of Alternatives 3 and 4 is clearly limited by the degree to which cap maintenance can be assured. The long-term effectiveness of Alternatives 1 and 2 is very low since these alternatives do not involve any physical remedial actions.

- Management of Short-Term Risks: Alternatives 3, 4, and 5 involve some short-term risk to workers implementing the removal, consolidation, and or capping; however, that risk will be mitigated by health and safety programs meeting OSHA and MTCA standards. Alternative 5 also involves some short-term risks associated with off-site transportation of recycled lead and lead containing soils; however transportation practices and emergency response mechanisms are in place to mitigate these risks. Alternatives 1 and 2 present no additional short-term risk since they do not involve any physical remedial action.

- Technical and Administrative Implementability: Alternative 5 ranks very high in terms of Implementability since it involves the application of proven technologies, the use or readily available personnel, equipment, and supplies, and the use of existing disposition facilities. Alternatives 3 and 4 are technically implementable for the same reasons; however there is a significant administrative issue arising from the requirement to leave lead-containing materials on site. Alternatives 1 and 2 are technically implementable as they do not involve any physical actions; however they raise major administrative issues.

- Consideration of Public Concerns: Alternative 5 is expected to address most public concerns since the lead and soils exceeding the cleanup standard will be removed from the site. Alternatives 1 through 4 all raise significant public concerns as they involve

leaving these materials on-site in locations that will be in or near the proposed public recreation areas.

Table 7-1 Revised Volume Estimates

Small Arms Range Designation	Volume of Impacted Grids (cubic yards) > 50mg/kg
Close Combat Range	30
25 Meter M60 /Pistol Range	486
Sub Machine Gun Range	0
TF Range	0
Rifle Range 1 & 2	3,119
Field Fire Rifle Ranges 1 & 2	372
Infiltration Course North	0
Field Firing Ranges 1&2 &Pistol	868
Undocumented Pistol Range	52
1,000 ft Range, 1,000 Machine	3,315
Combat Pistol Range	493
Machine Gun Range North	268
Machine Gun Range South	59
M31 Sub-Caliber Ranges 1 & 2	30
25 m & Machine Gun Range	2,080
Infiltration Course South	59
25M Record Fire Field Range	1,331
Total (cubic yards)	**12,562**

7.5 Summary and Recommendations

The evaluation of the five candidate alternative action is summarized as follows:

- Alternative 1 – No Action does not meet the threshold requirements.
- Alternative 2 – Institutional Controls partially meets the threshold requirements and is ranked very low in terms of permanence.
- Alternative 3 - Containment and Alternative 4 - Consolidation and Containment – meet the threshold requirements except for consideration of public concerns and ranks lower in terms of permanence than Alternative 5.
- Alternative 5 – Excavation and Off-site Disposal or Recycling meets the threshold requirements, addresses public concerns, and ranks highest in terms of permanence.

Therefore, the recommended alternative for remediation of site soils is excavation and removal of contaminated soil.

The selected cleanup alternative – Alternative 5 – provides the most permanent solution to the contaminated soil at the Small Arms Ranges. Metallic, particulate lead will be removed by post-excavation screening and recycled. Highly contaminated soils with lead concentrations exceeding TCLP criteria will be stabilized prior to disposal in an approved landfill. Less contaminated soils will be removed to an appropriate residual waste landfill. Due to the nature of the contamination, this cleanup alternative offers the most permanent solution for cleaning up lead contaminated soil. Therefore, a disproportionate cost analysis specified in WAC 173-340-360 (3) is not appropriate since it is obvious that the selected alternative uses permanent solutions to the maximum extent practicable. That is, the selected alternative when compared to the other alternatives more favorable satisfies the evaluation criteria: protectiveness, permanence, short and long term effectiveness, implementability, and public concerns.

It is proposed that the 11,300 cubic yards proposed for remediation be managed according to Alternate 5. Table 7-1 identifies these soil volumes by Small Arms Range location.

Due to concerns related to the potential presence of munitions and explosives of concern (MEC) at these Small Arms Ranges, this remedial action should be implemented in two stages, as follows:

- An Interim Cleanup Action consisting of brush removal and a MEC clearance.

- A Final Cleanup Action consisting of soil excavation, confirmatory testing to verify excavation completion, excavated soils screening, recovered lead recycling, excavated soils testing for disposal management, and excavated, categorized soils disposal at appropriate treatment and/or disposal facilities.

8.0 REFERENCES

AEM 2003a. Work Plan for Soil Sampling in Firing Ranges and Demolition Areas 2 and 3, Sampling and Analysis Plan – Soil, Quality Assurance Project Plan, Site Safety and Health Plan, Data Management Plan, and Waste Management and Minimization Plan. Prepared for U.S. Army Engineering District Norfolk, Norfolk, Virginia. Prepared by Atlanta Environmental Management. 17 February 2003.

AEM, 2003b. Draft Site Investigation Report, Small Arms Ranges and Demolition Areas 2 and 3. Camp Bonneville, Vancouver, Washington. Prepared for U.S. Army by Atlanta Environmental Management (AEM). April 18, 2003.

Ecology, 1994. Natural Background Soil Metals Concentrations in Washington State, Toxics Cleanup Program, Dept. of Ecology, Publication #94-115. Figure 51, page 12-10.

Ecology, 2001. Cleanup Levels and Risk Calculations under the Model Toxics Control Act Cleanup Regulations (CLARC). Version 3.1. Part II, Soil Cleanup Levels for Unrestricted Land Use, Table 2. Publication No. 94-145. November 2001.

Environmental Science and Engineering, Inc. 1983. Installation Assessment of the HQ, I Corps and Ft. Lewis, Washington and the Sub installation Yakima Firing Center, Camp Bonneville, and Vancouver Barracks.

Geo Recon International. 1981. Cultural Resources Survey, Forest Management Project, Ft. Lewis and Camp Bonneville, Washington, for U.S. Army, Ft. Lewis.

Hart Crowser. 1996. Petroleum Contaminated Soil Investigation, Former Tank no.7-CMBPN, Building no. 4475, Camp Bonneville Washington. Contract No. DACA67-93-D-1004. September 1996.

Hart Crowser. 2000. Final Project Completion Report Surface Water Investigation of Lacamas Creek. Camp Bonneville, Vancouver, Washington. Prepared for US Army Corp of Engineers, Seattle District. March 10, 2000.

Interstate Technology and Regulatory Council (ITRC). 2003. Technical and Regulatory Guidelines. Characterization and Remediation of Soils at Closed Small Arms Firing Ranges. Prepared by ITRC, Small Arms firing Range Team.

Larson, Lynn L. 1980. Cultural Resource Reconnaissance of Forest Management Tracts on Fort Lewis and Camp Bonneville. Office of Public Archaeology, Institute for Environmental Studies, University of Washington, Reconnaissance Report No. 34.

Miles 1972. Miles, C.D., et. al. Inhibition of Photosystem II in Isolated Chloroplasts by Lead. Plant Physiology 49:820-825.

Mundorff, MR. 1964. Geology and groundwater conditions of Clark County, Washington, with a description of major alluvial aquifer supply along the Columbia River: U.S. Geological Survey Water Supply Paper 1600, 268 p.

Oak Ridge National Laboratory (ORNL). 1997. Toxicological Benchmarks for Screening Potential Contaminants of concern for effects on Terrestrial Plants. 1997 Revision.

Phillips, WIMP. 1987. Geologic map of the Vancouver quadrangle, Washington and Oregon: Washington Division of Geology and Earth Resources Open File Report 87-10, scale 1:100,000.

Project Performance Corporation. 2003. Work Plan for Interim Actions at Small Arms Range Berms and Fire Support Areas. Camp Bonneville, Vancouver, Washington. Draft. March 31, 2003.

Shannon & Wilson. 1999a. Final Report Volume 1 Multi-Sites Investigations, Camp Bonneville, Washington. Contract No. DACA 67-94-D-1014. July 1999.

Shannon & Wilson 1999b. Final Landfill 4 Investigation Report, Camp Bonneville, Washington. Contract DACA 67-94-D-1014. August 1999.

URS. 2001. Expanded Site Investigation, Landfill 4 Demolition Area 1, Camp Bonneville, Vancouver, Washington. May 2001.

Venkatakrishnan, R., Bond, J. G., and Kauffman, J.D., 1980. Geologic Linears of the Northern Part of the Cascade Range, Oregon. State of Oregon, Department of Geology and Mineral Industries. Special Paper 12.

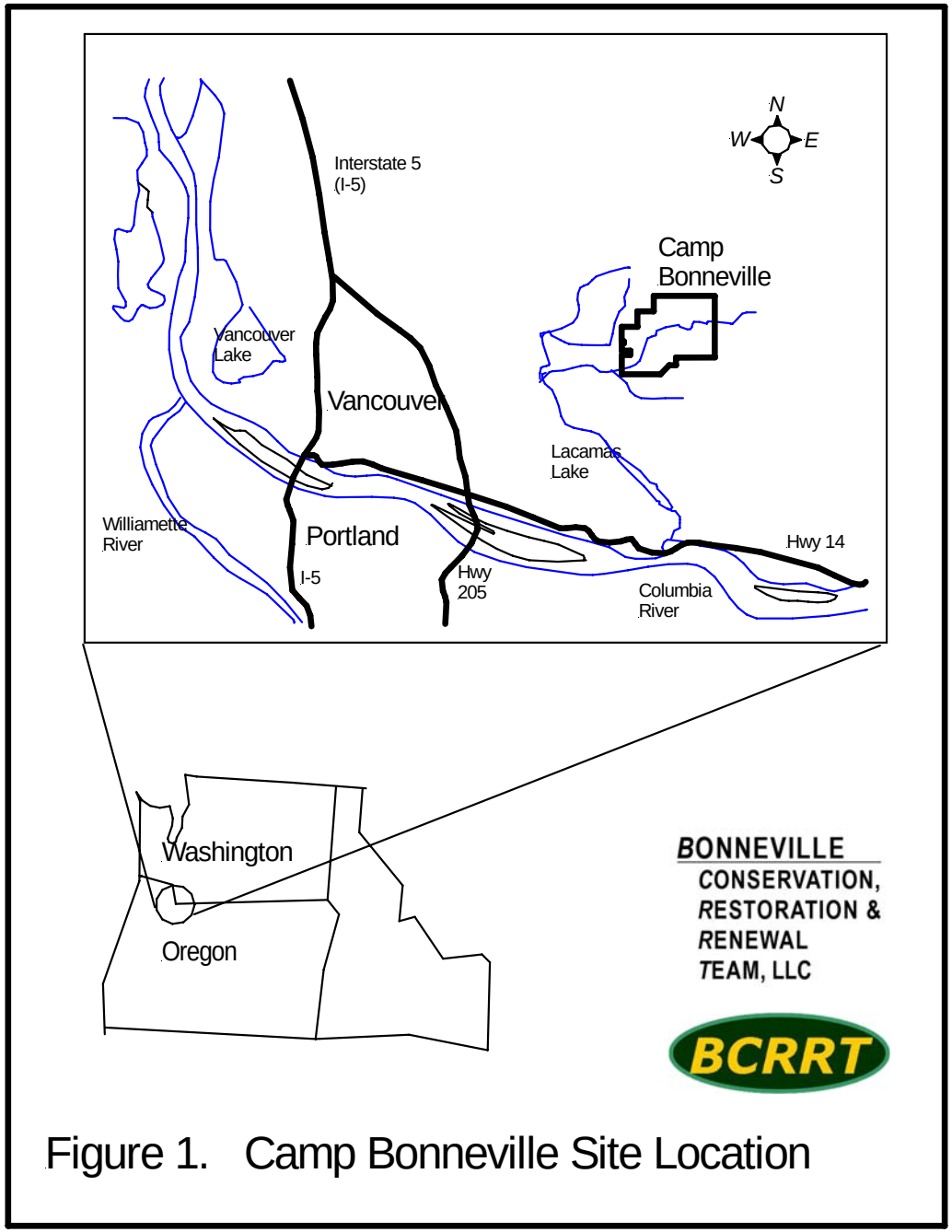
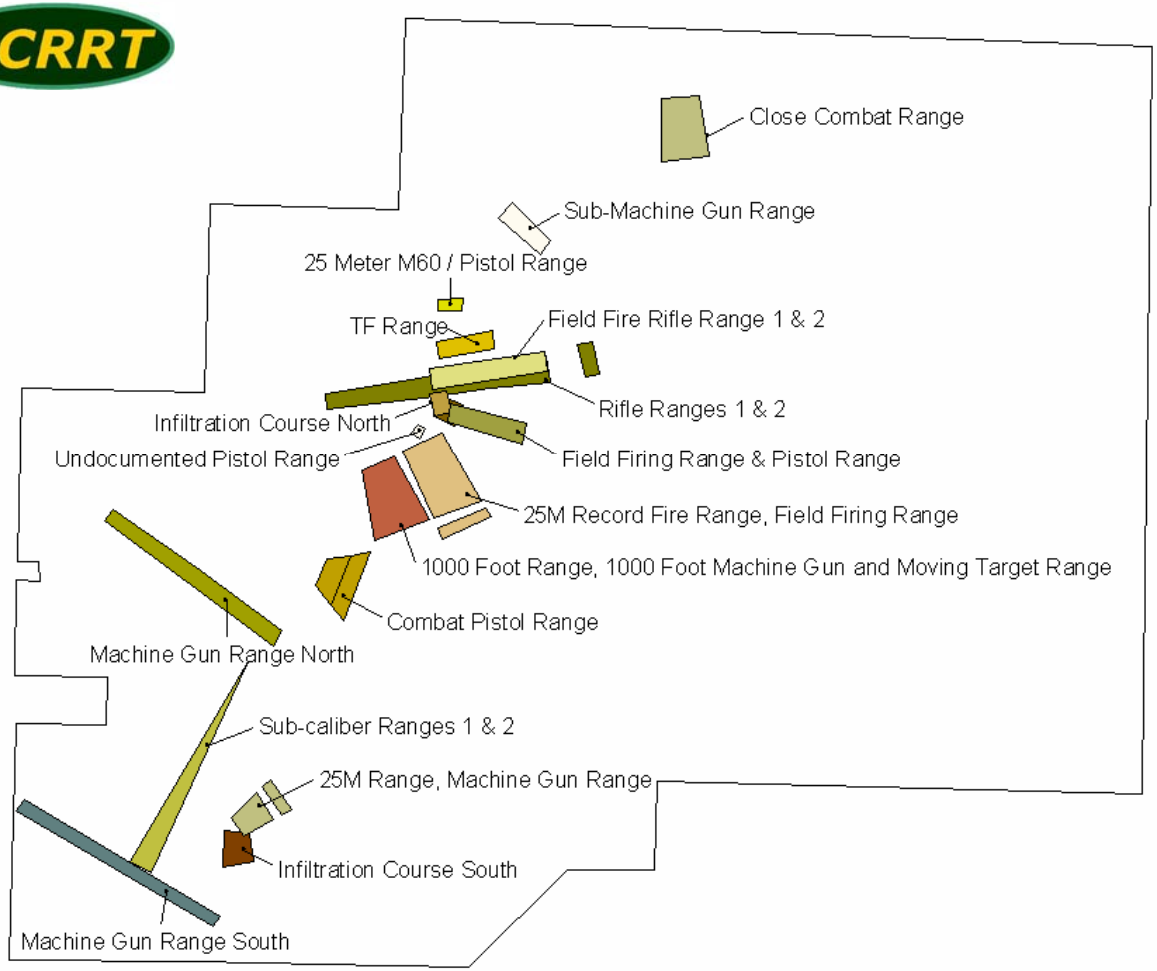


Figure 1. Camp Bonneville Site Location

BONNEVILLE CONSERVATION, RESTORATION & RENEWAL TEAM, LLC

BCRRT

Figure 2
Small Arms Ranges



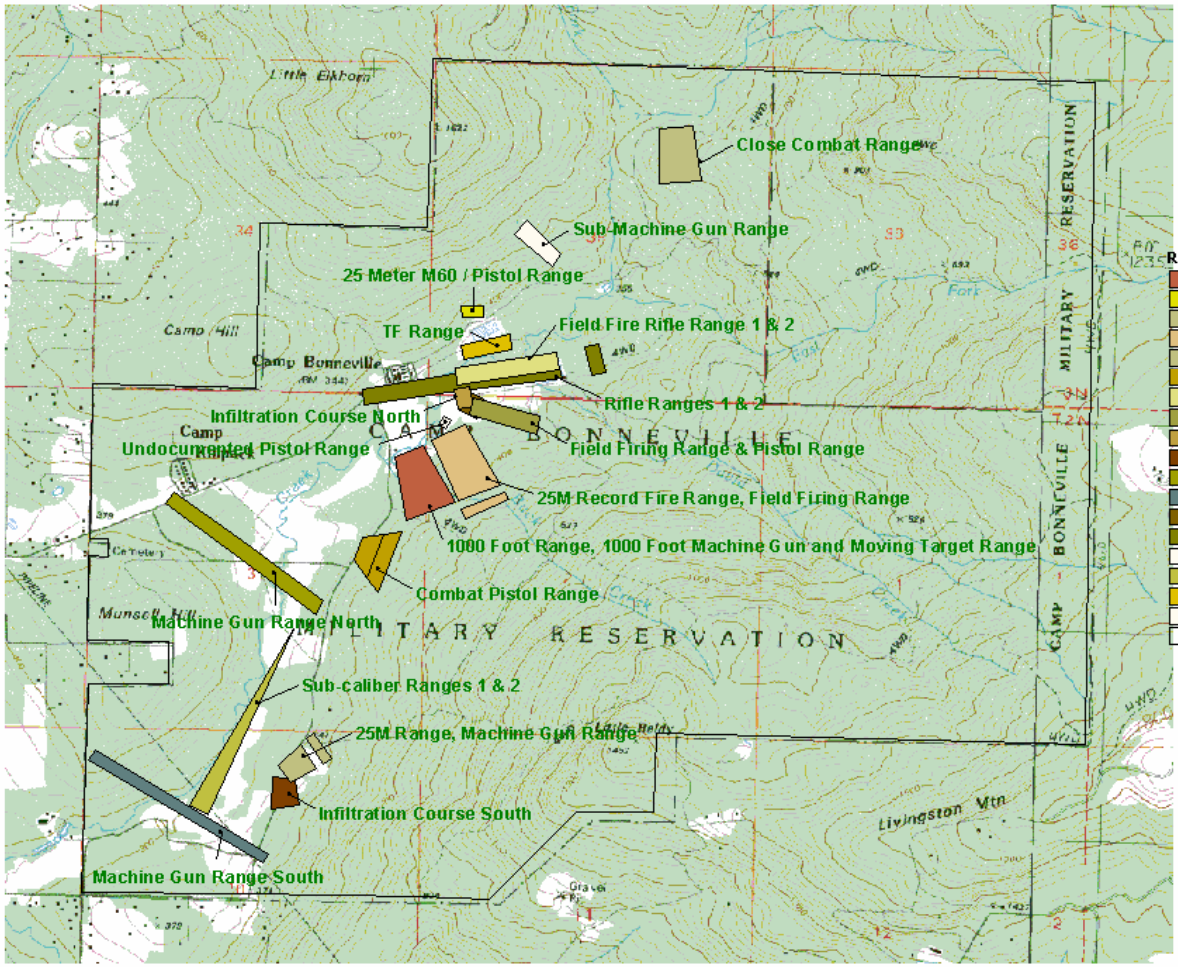
Range Footprints

- 1000 Foot Range, 1000 Foot Machine Gun and Moving Target Range
- 25 Meter M60 / Pistol Range
- 25M Range, Machine Gun Range
- 25M Record Fire Range, Field Firing Range
- Close Combat Range
- Combat Pistol Range
- Field Fire Rifle Range 1 & 2
- Field Firing Range & Pistol Range
- Infiltration Course North
- Infiltration Course South
- Machine Gun Range North
- Machine Gun Range South
- Pistol Range
- Rifle Ranges 1 & 2
- Sub-Machine Gun Range
- Sub-caliber Ranges 1 & 2
- TF Range
- Undocumented Pistol Range
- Camp Bonneville Boundary

N W E S

1 0 1 2 Miles

Figure 3
Camp Bonneville Topography



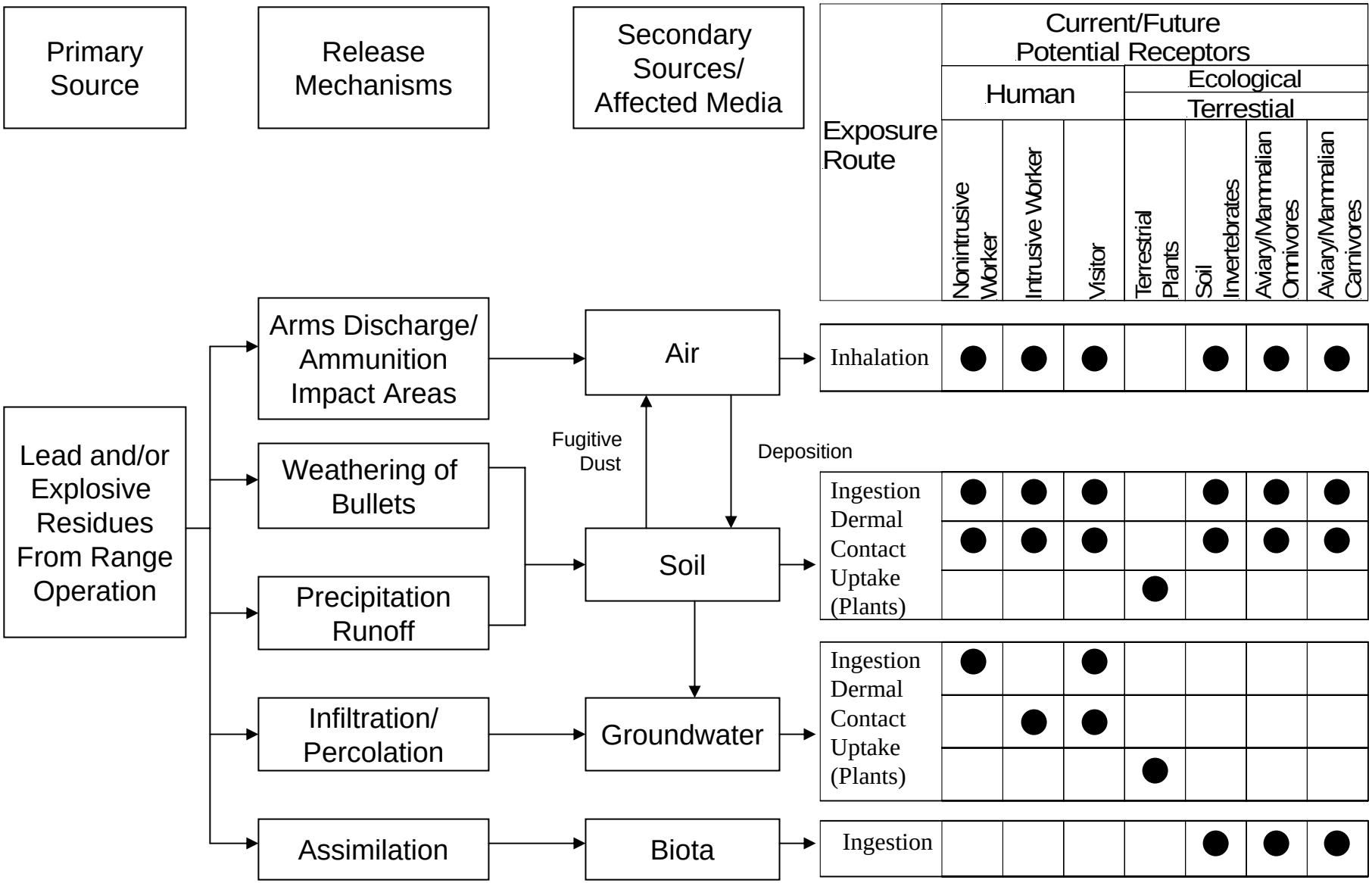
BONNEVILLE CONSERVATION, RESTORATION & RENEWAL TEAM, LLC

BCRRT

BONNEVILLE CONSERVATION, RESTORATION & RENEWAL TEAM, LLC

Figure 4
Conceptual Site Model
Potential Exposure Pathways at Small Arms Ranges

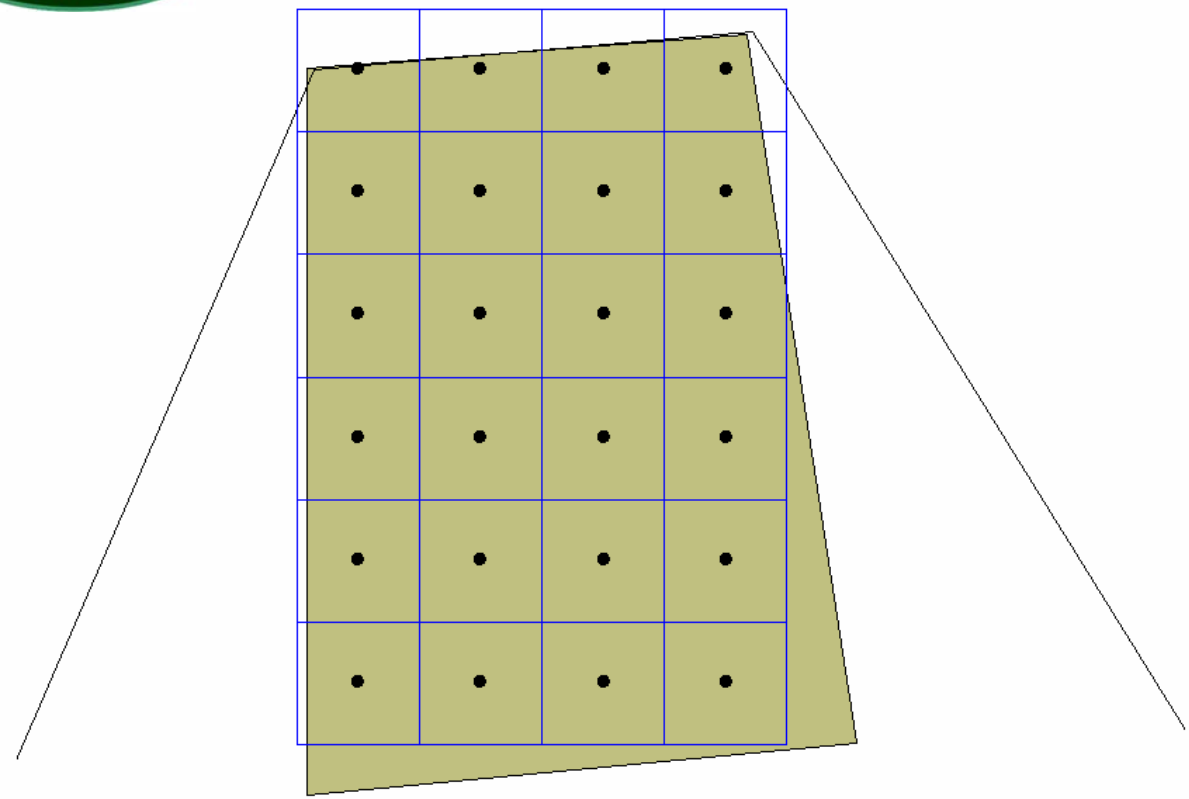
BCRRT

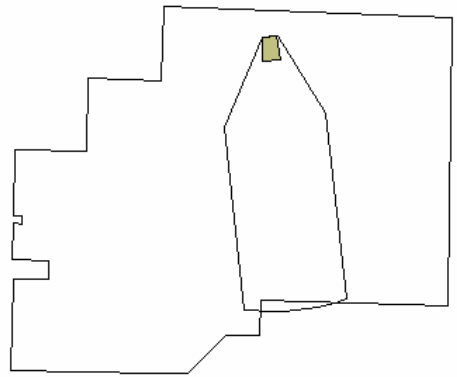


BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

Figure 5
Close Combat Range





Sampling Grid Center Points
Sampling Grid
Range Fan
Range Fan
Range Footprint
Close Combat Range

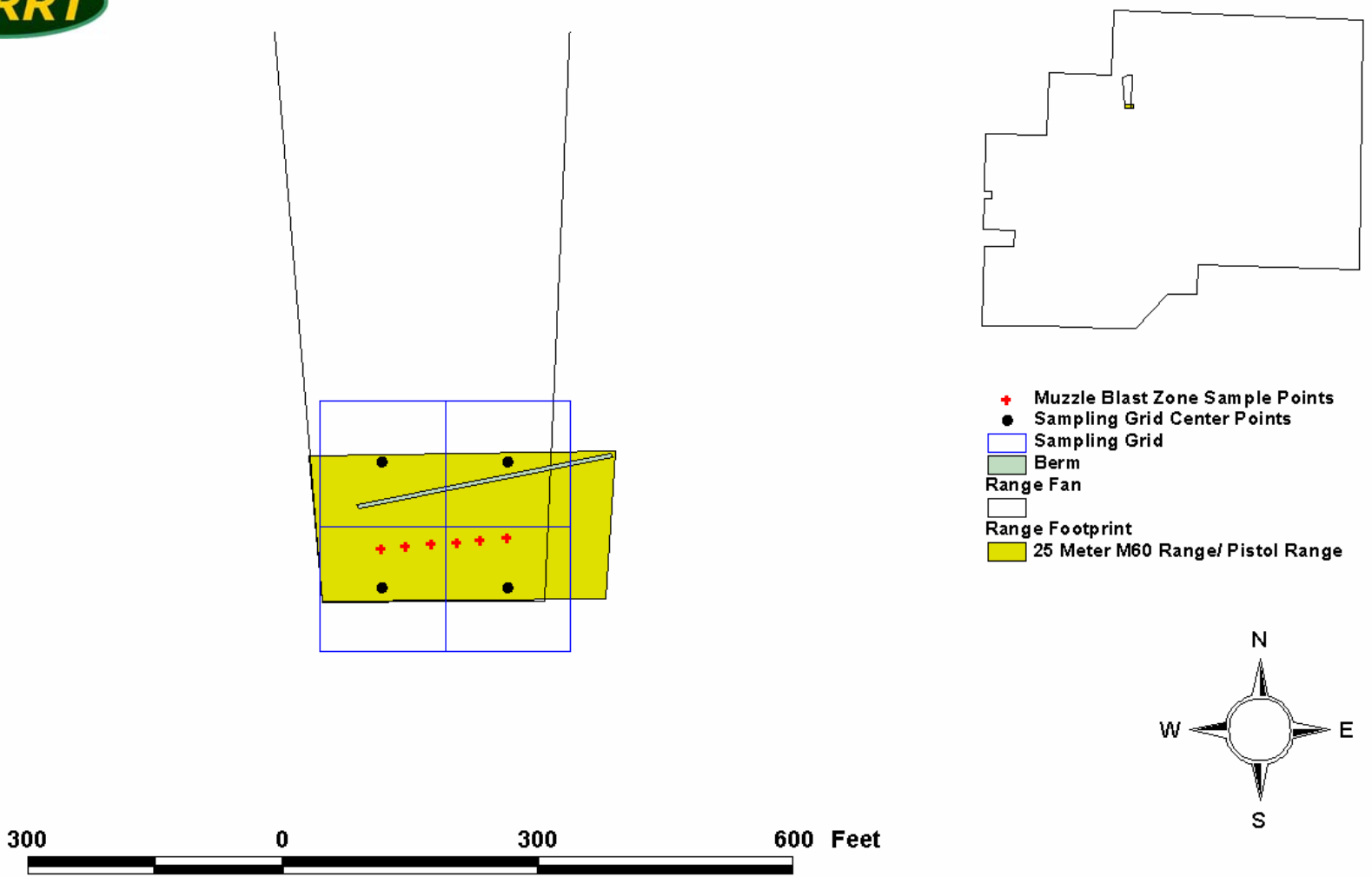
N
W
E
S

400 0 400 800 Feet

BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

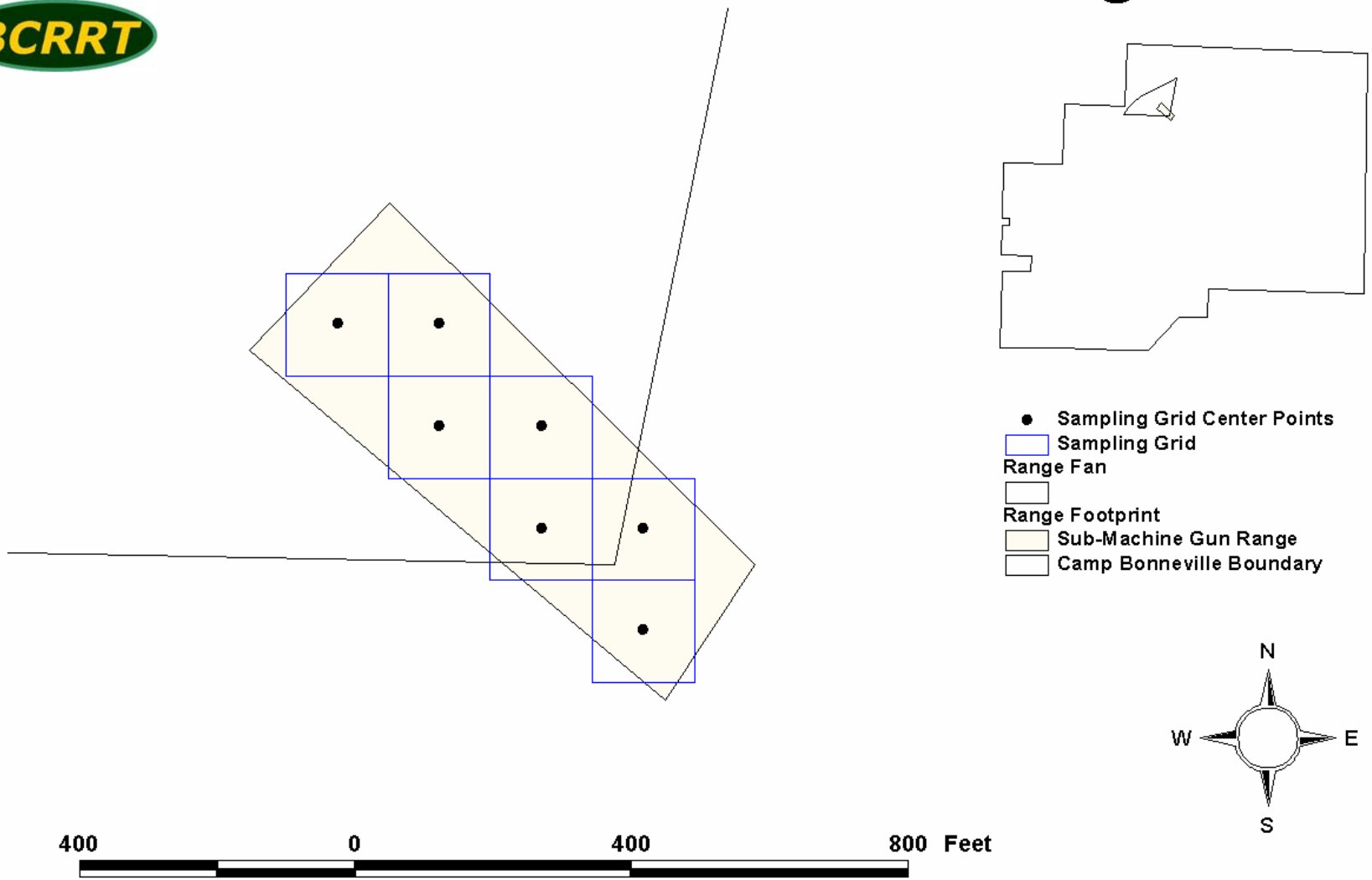
Figure 6
25-m M60 Range/Pistol Range



BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

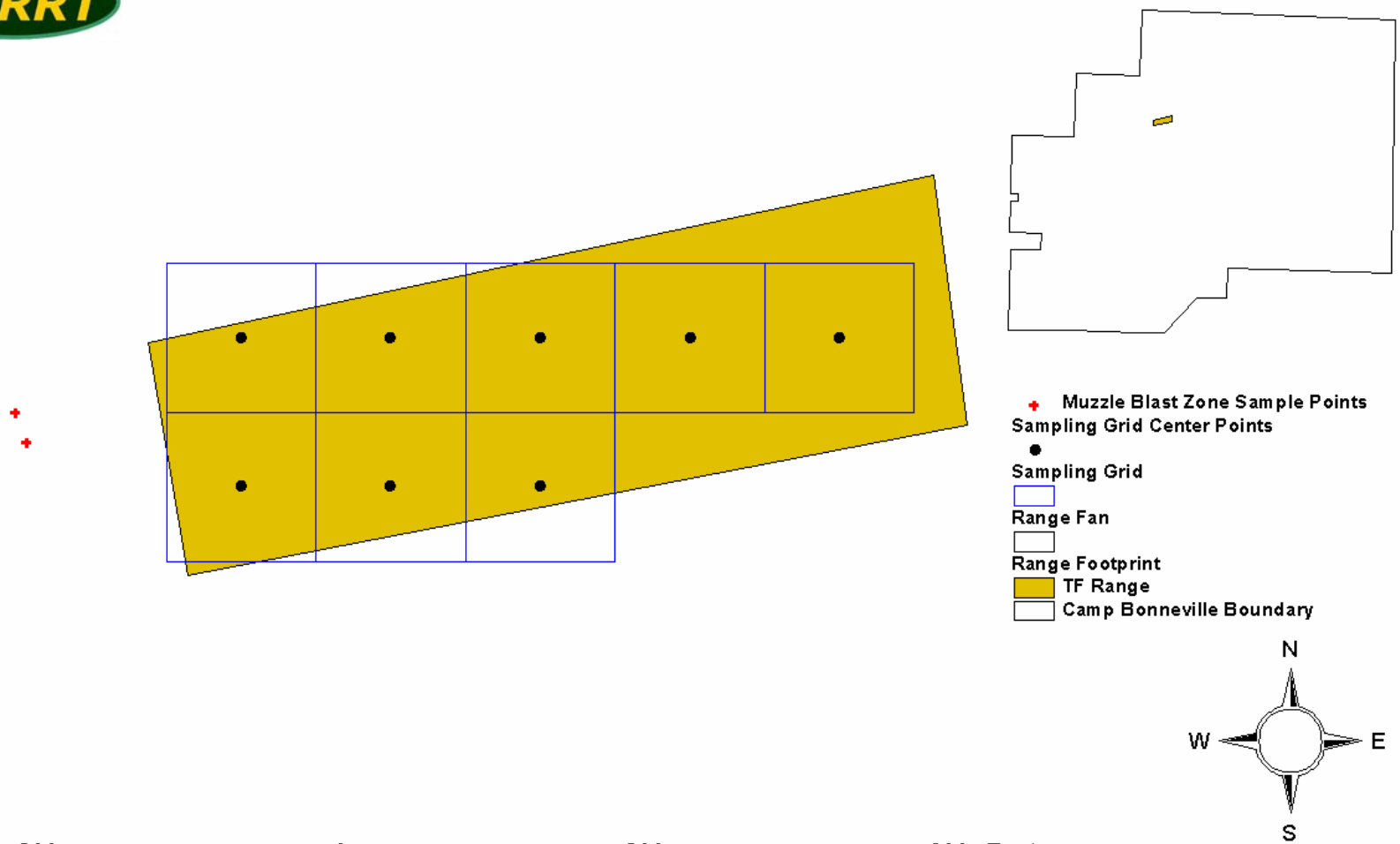
Figure 7
Sub Machine Gun Range



BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

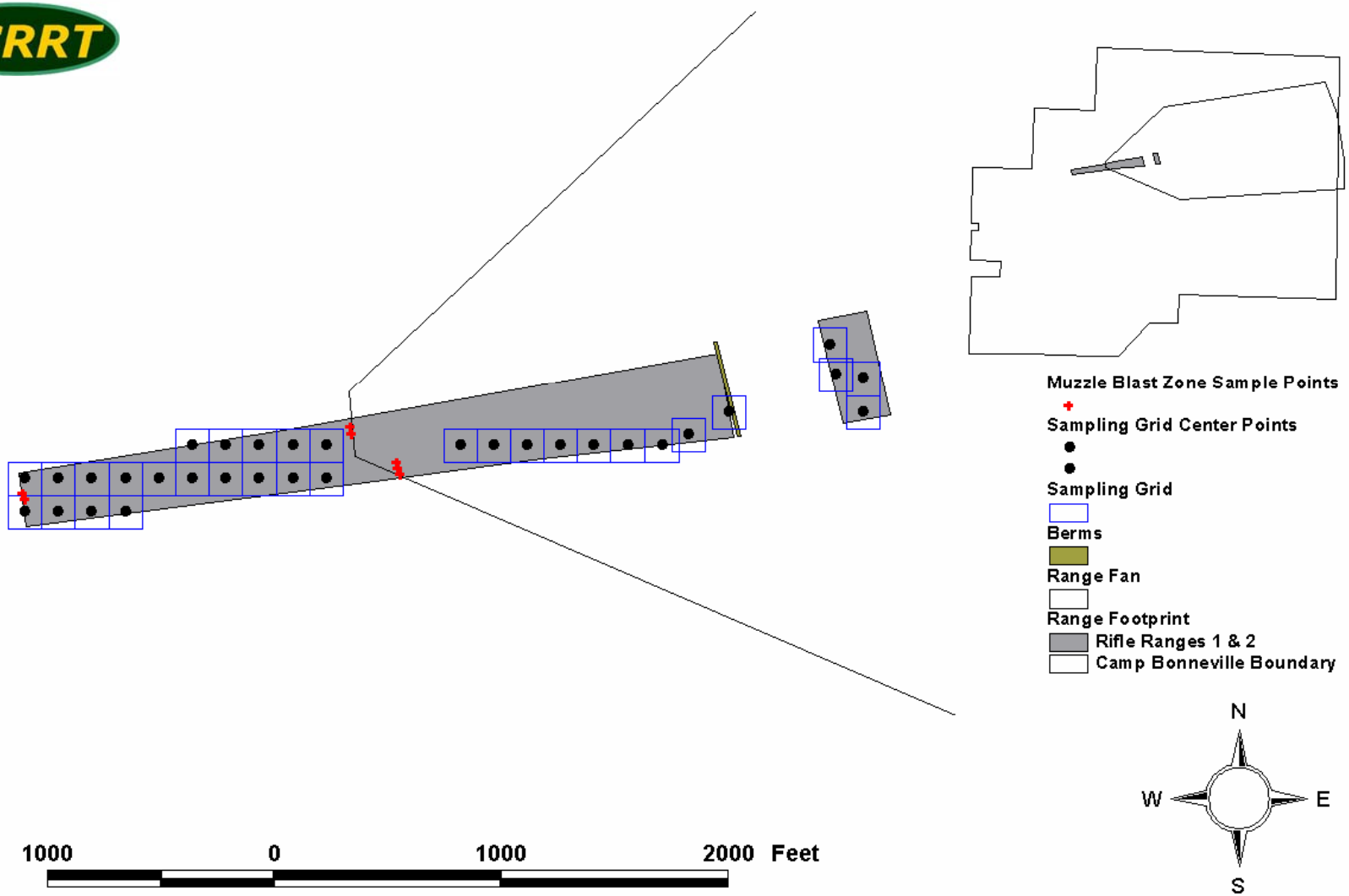
Figure 8
TF Range



BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

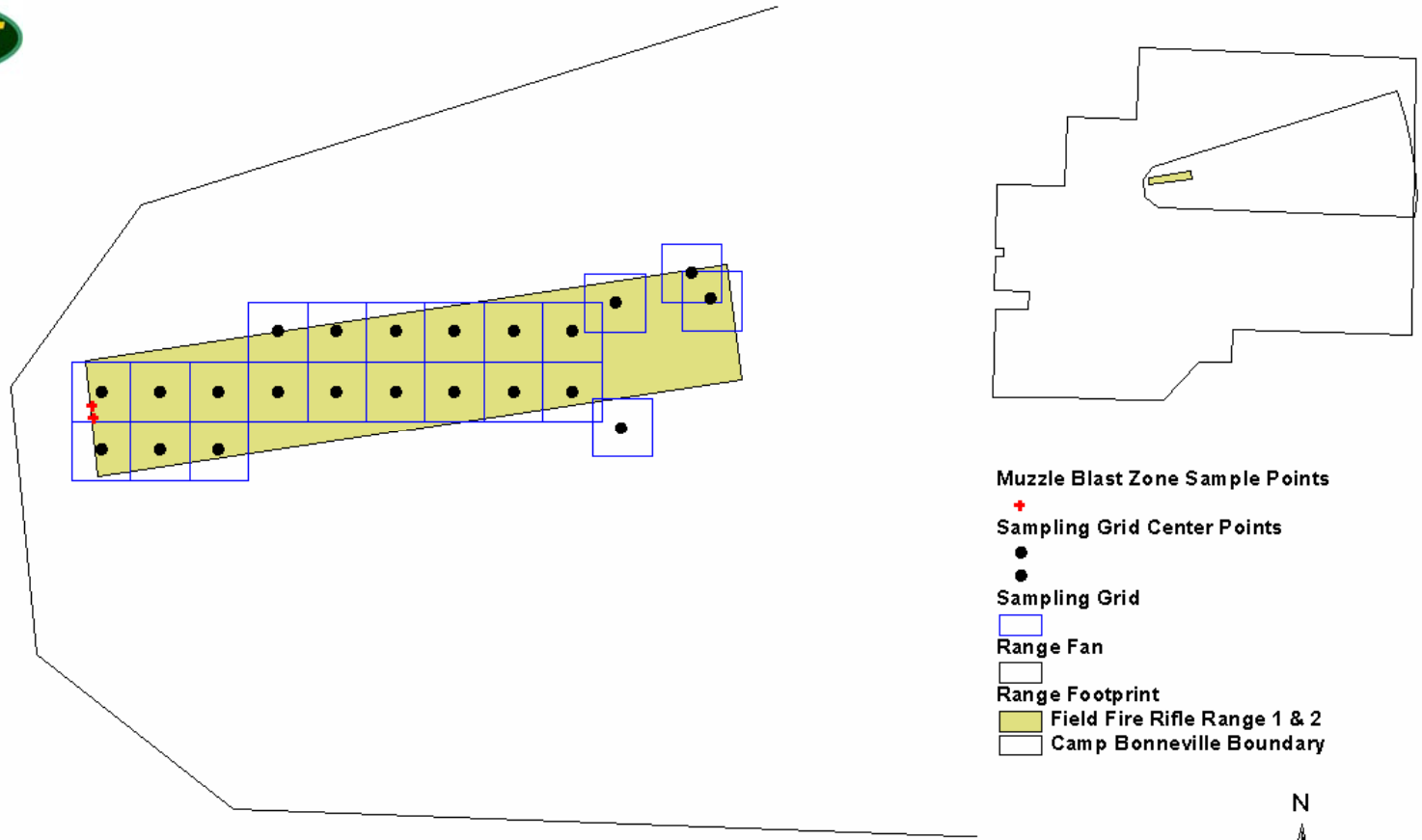
Figure 9
Rifle Ranges 1 & 2



BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

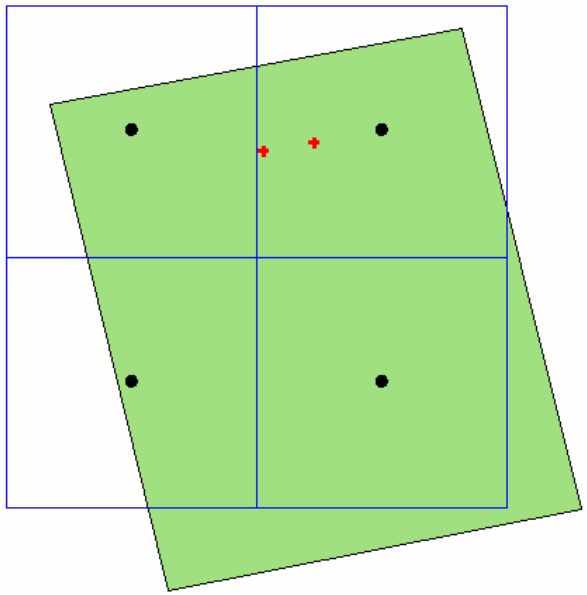
Figure 10
Field Fire Rifle Range 1 & 2

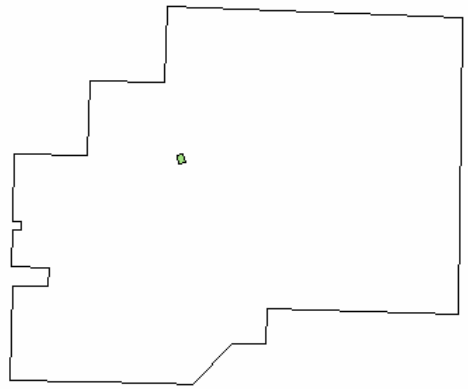


BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

Figure 11
Infiltration Course North





Muzzle Blast Zone Sample Points

Sampling Grid Center Points

Sampling Grid

Range Footprint

Infiltration Course North

Camp Bonneville Boundary

N

W E

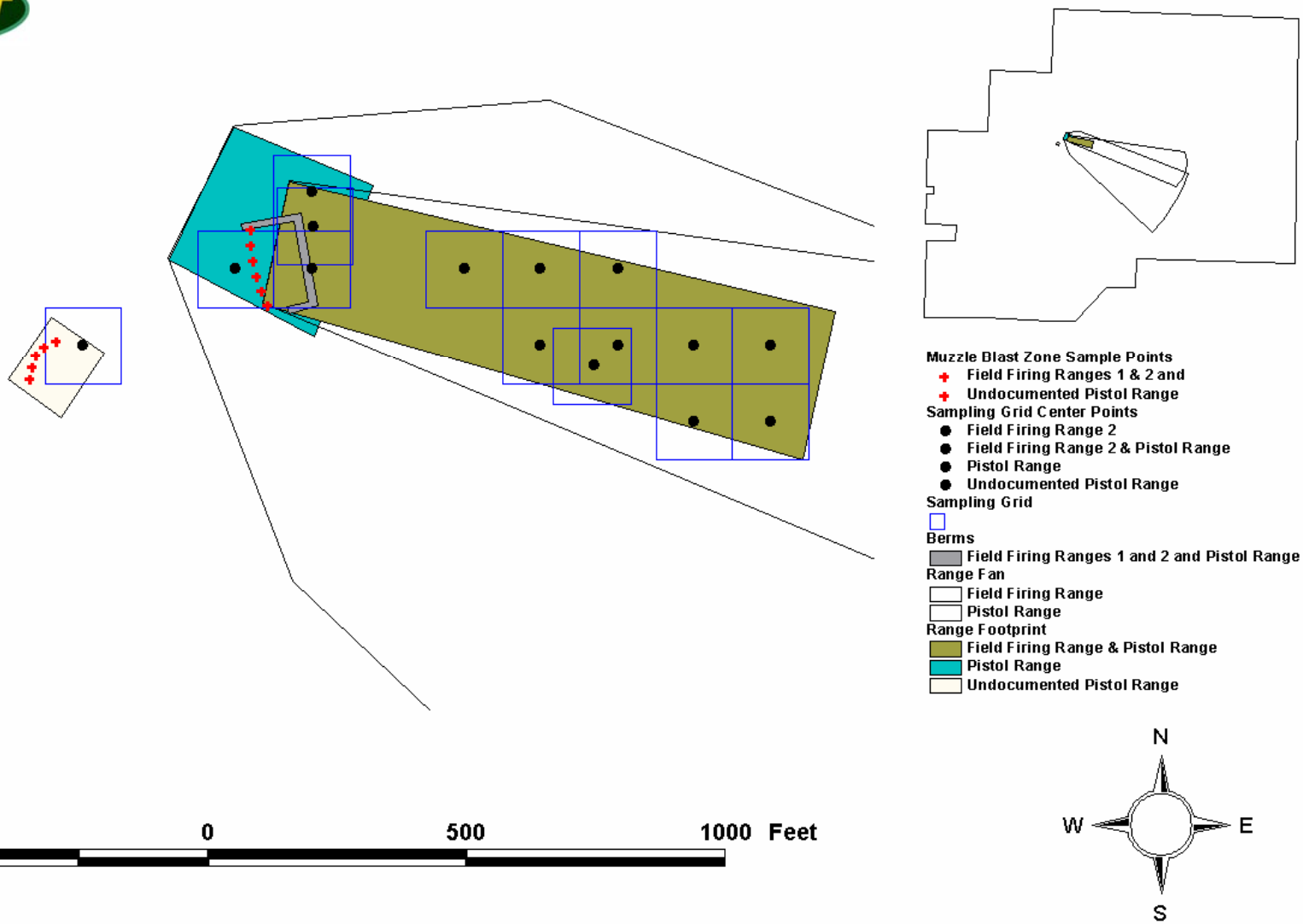
S

200 0 200 400 Feet

BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

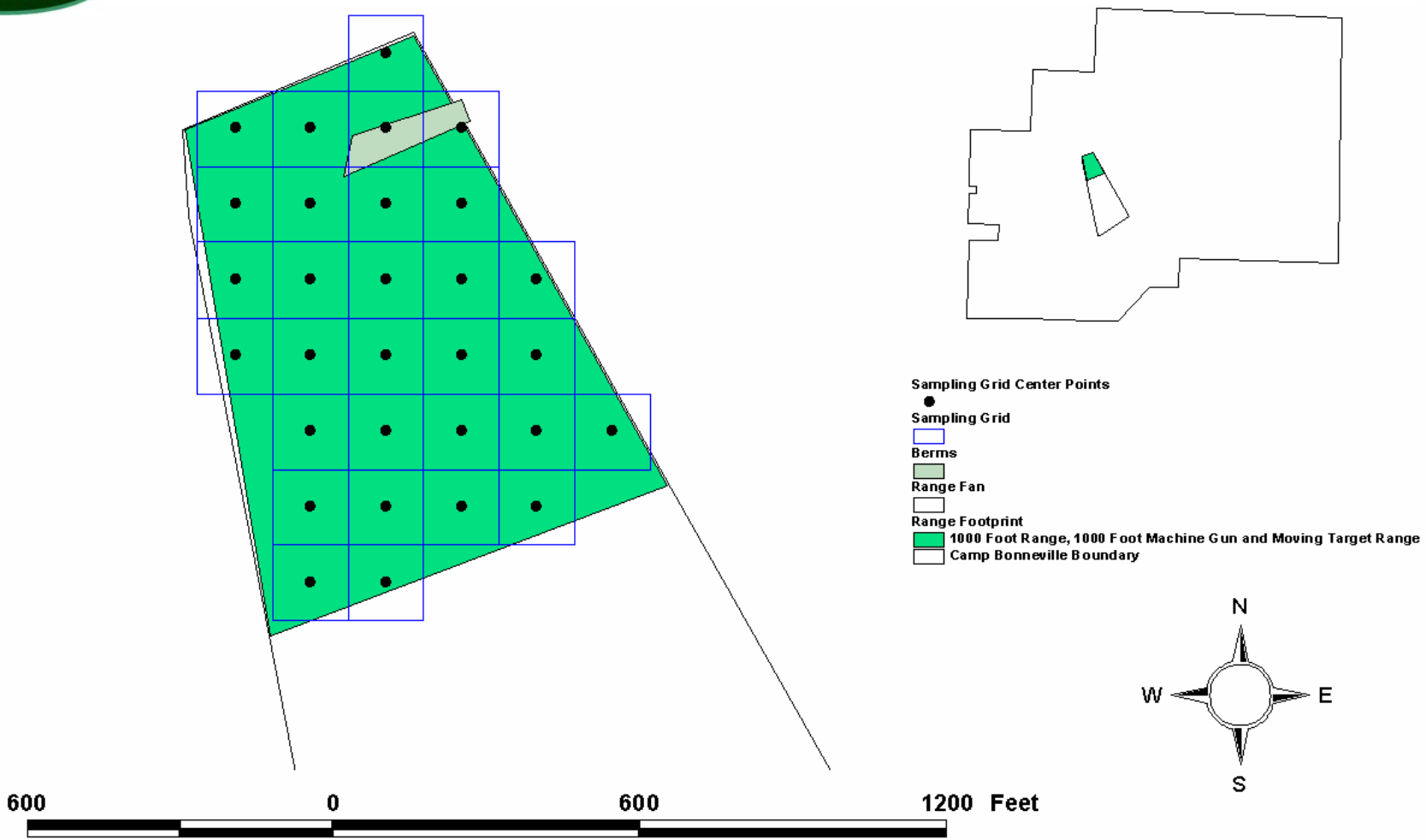
Figure 12
Field Firing Ranges, Pistol Range, and Undocumented Pistol Range



BONNEVILLE CONSERVATION, RESTORATION & RENEWAL TEAM, LLC

BCRRT

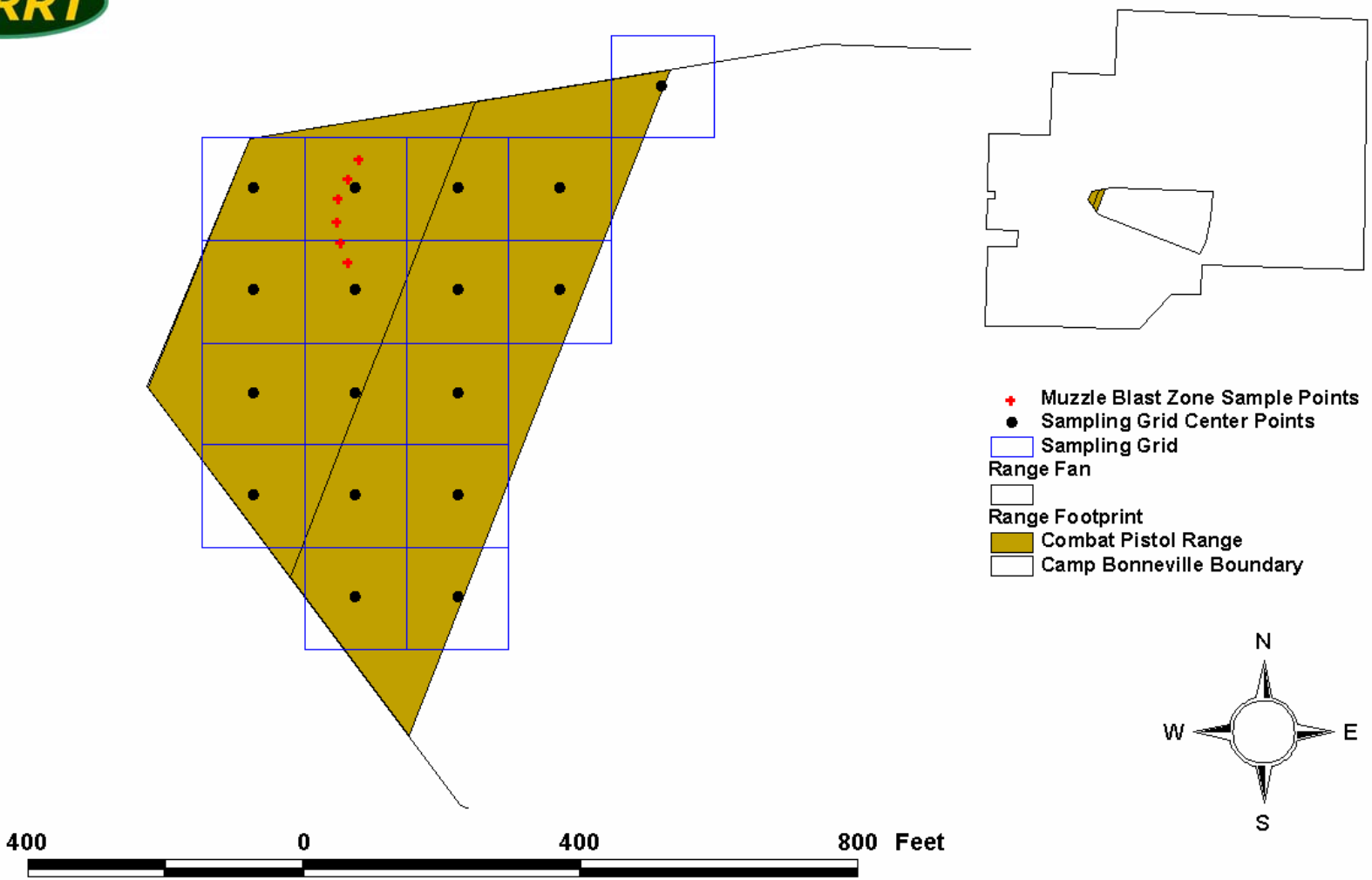
Figure 13
1000-ft Range, 1000-ft Machine Gun and Moving Target Range



BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

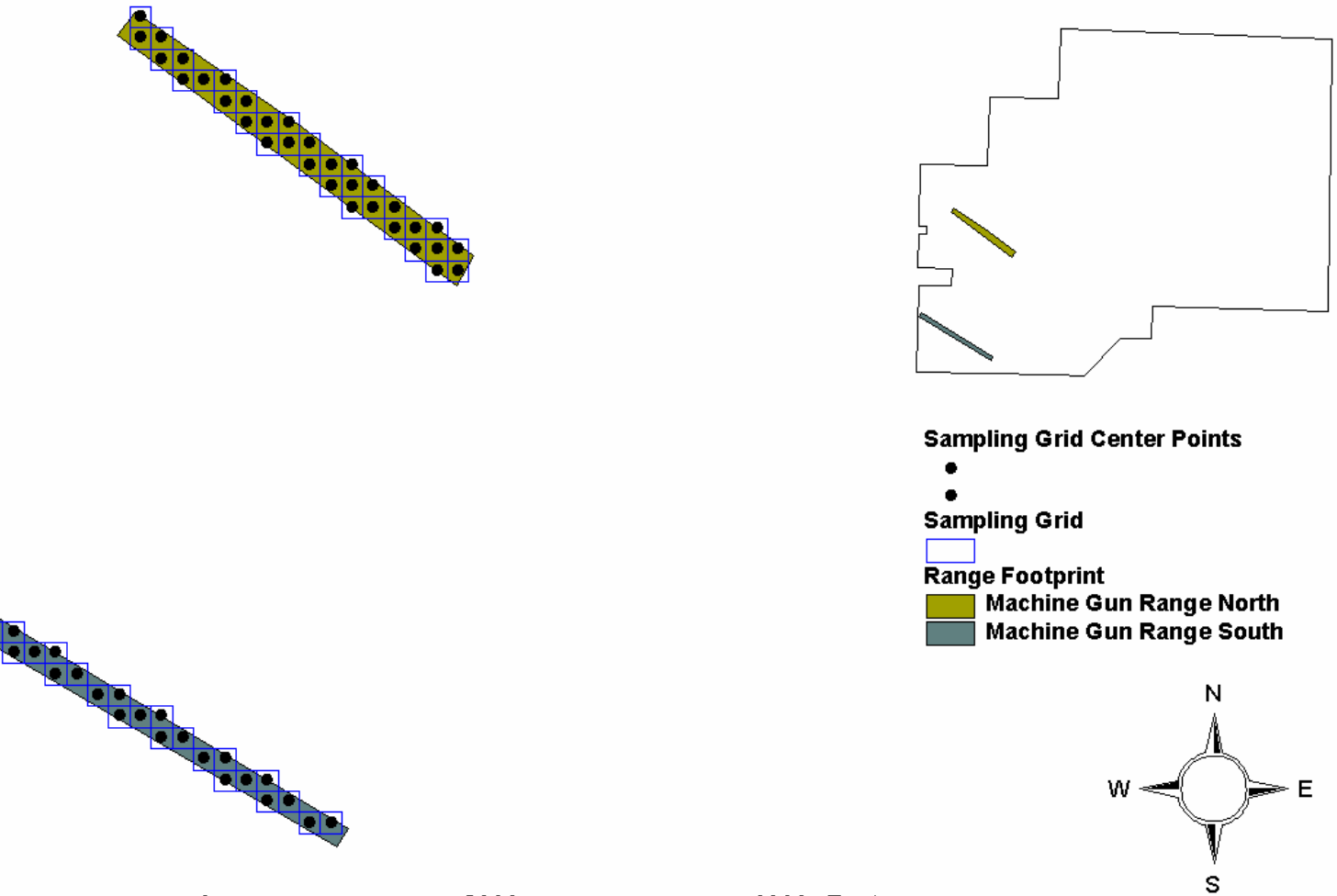
Figure 14
Combat Pistol Range



BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

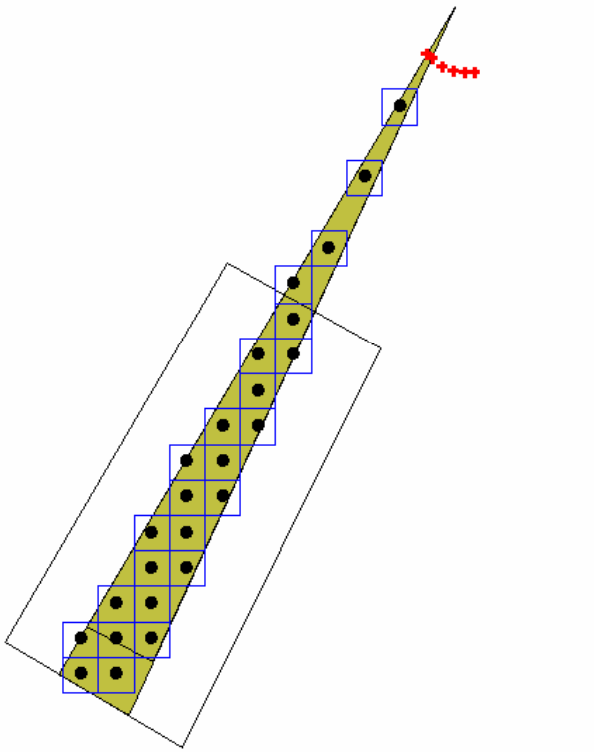
Figure 15
Machine Gun Ranges (North and South)

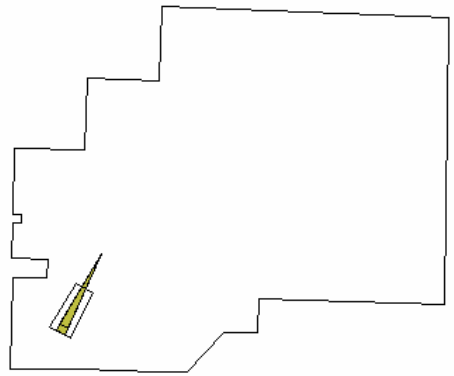


BONNEVILLE CONSERVATION, RESTORATION & RENEWAL TEAM, LLC

BCRRT

Figure 16
M31 Sub-Caliber Ranges 1 & 2





Muzzle Blast Zone Sample Points

Sampling Grid Center Points

Sampling Grid

Range Fan

Range Footprint

M31 Sub-caliber Ranges 1 & 2

N

W E

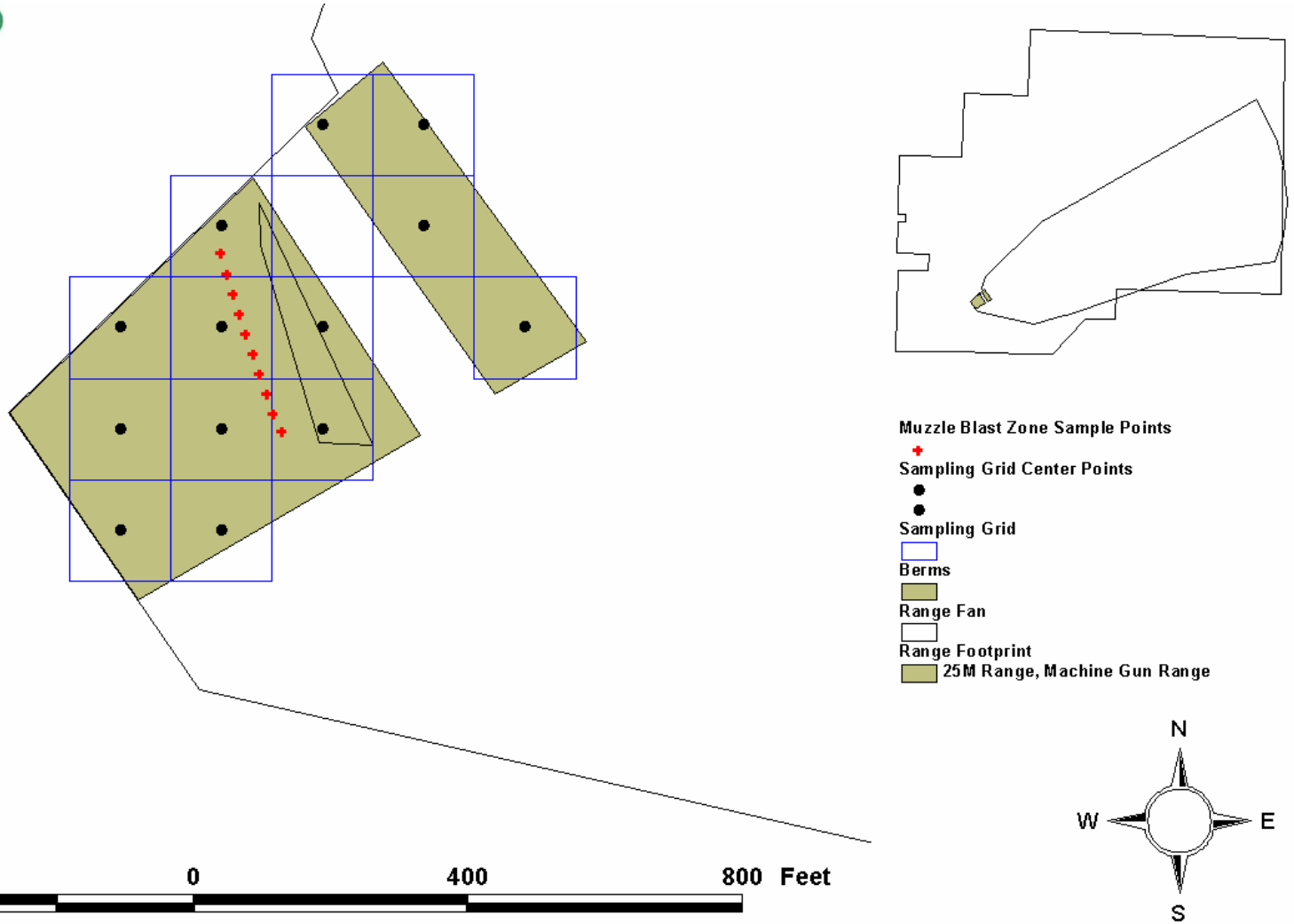
S

1000 0 1000 2000 Feet

BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

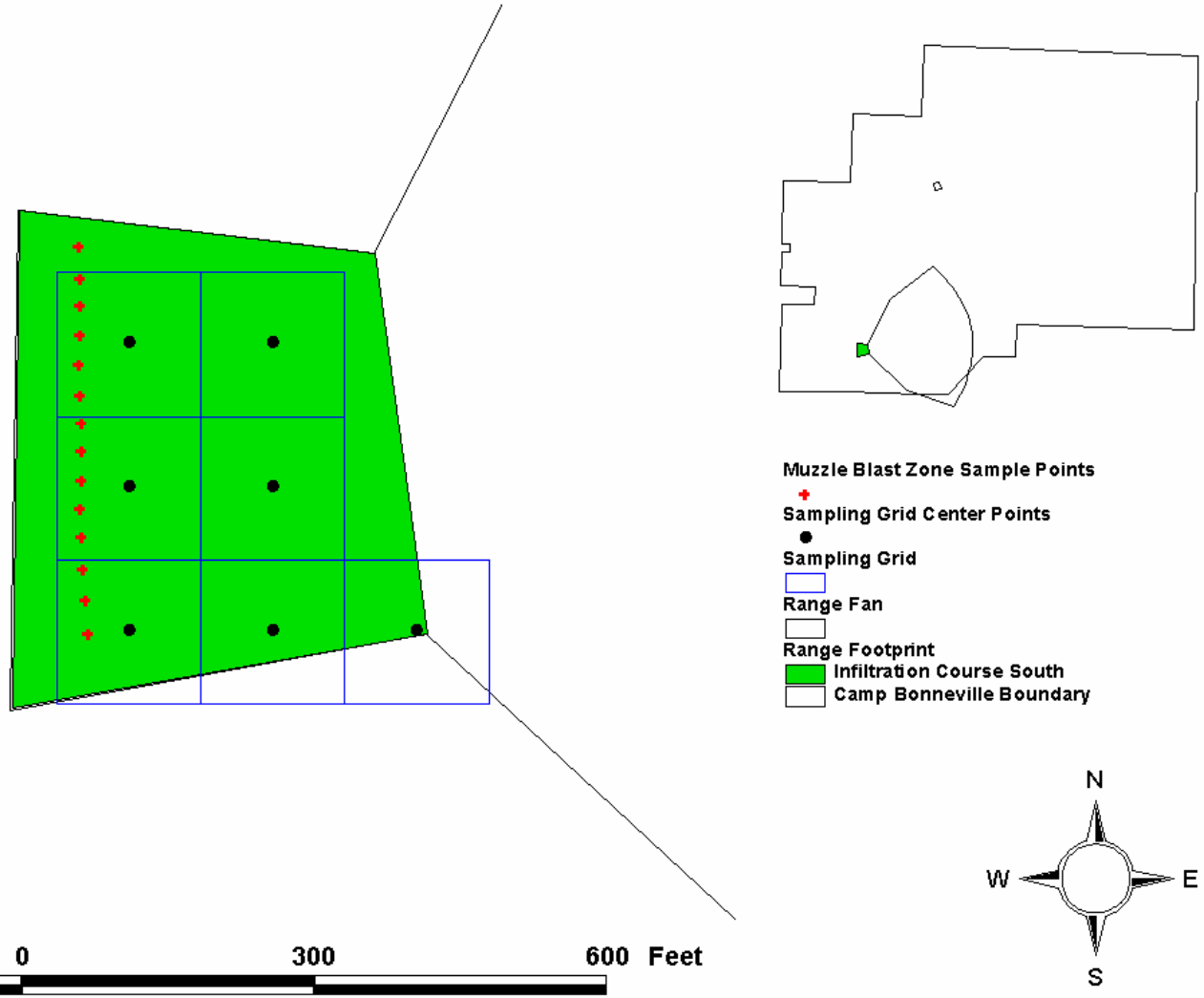
Figure 17
25-m and Machine Gun Range



BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

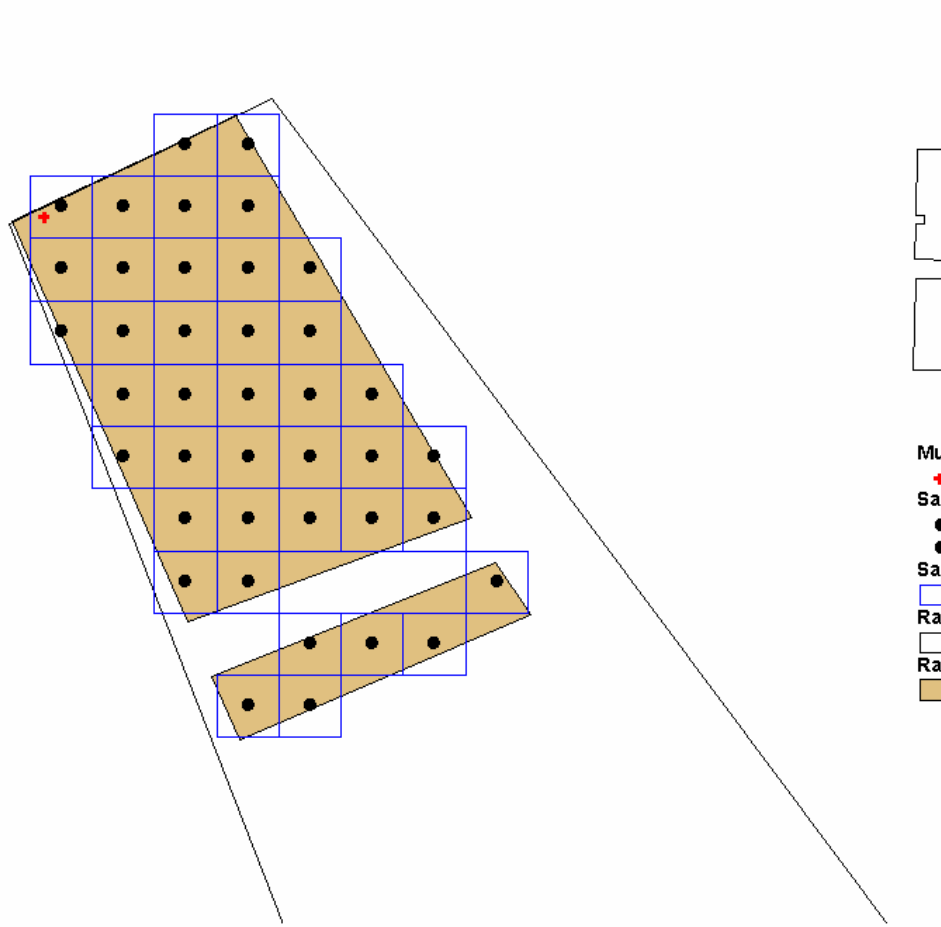
Figure 18
Infiltration Course South

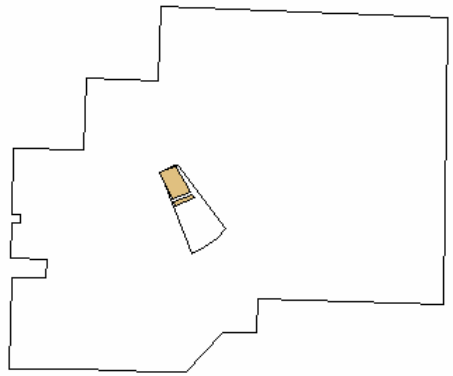


BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

Figure 19
25M Record Fire Field Range, Field Firing Range





Muzzle Blast Zone Sample Points

Sampling Grid Center Points

Sampling Grid

Range Fan

Range Footprint

25M Record Fire Range, Field Firing Range

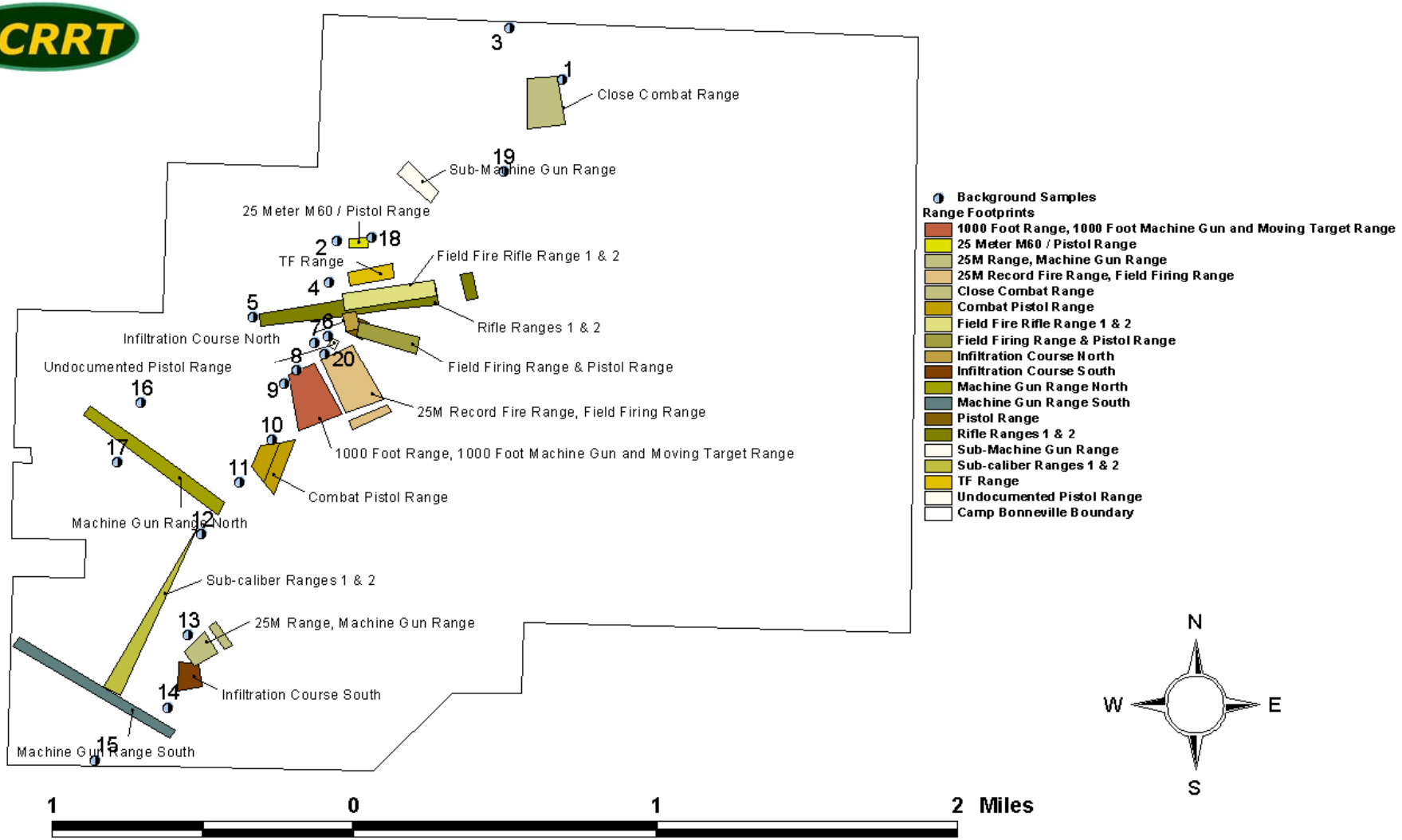
N
W E
S

800 0 800 1600 Feet

BONNEVILLE CONSERVATION, RESTORATION & RENEWAL TEAM, LLC

BCRRT

Figure 20
Locations of Background Samples



BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

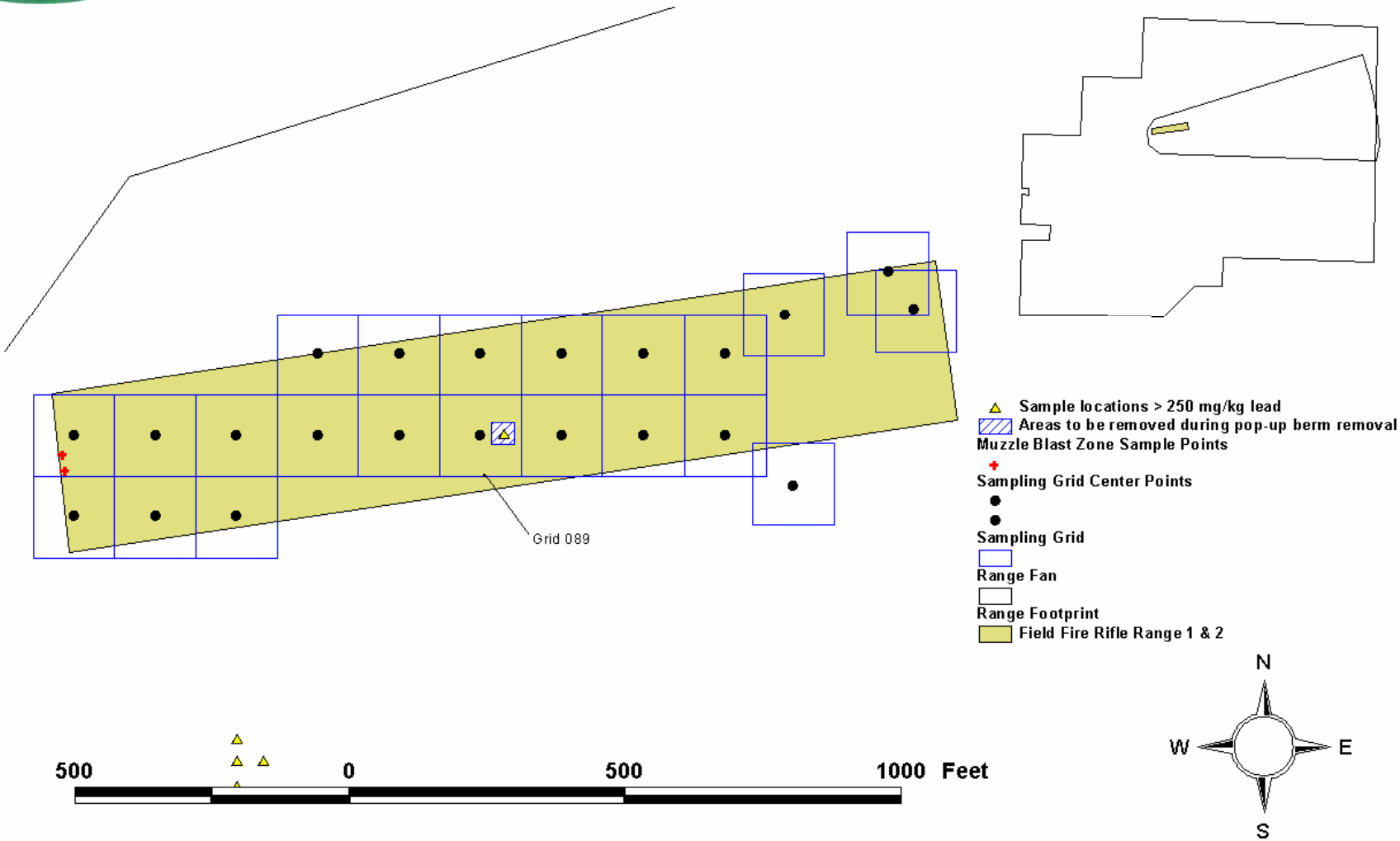
BCRRT

Figure 21
Rifle Ranges 1 & 2
Areas to be Removed

BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

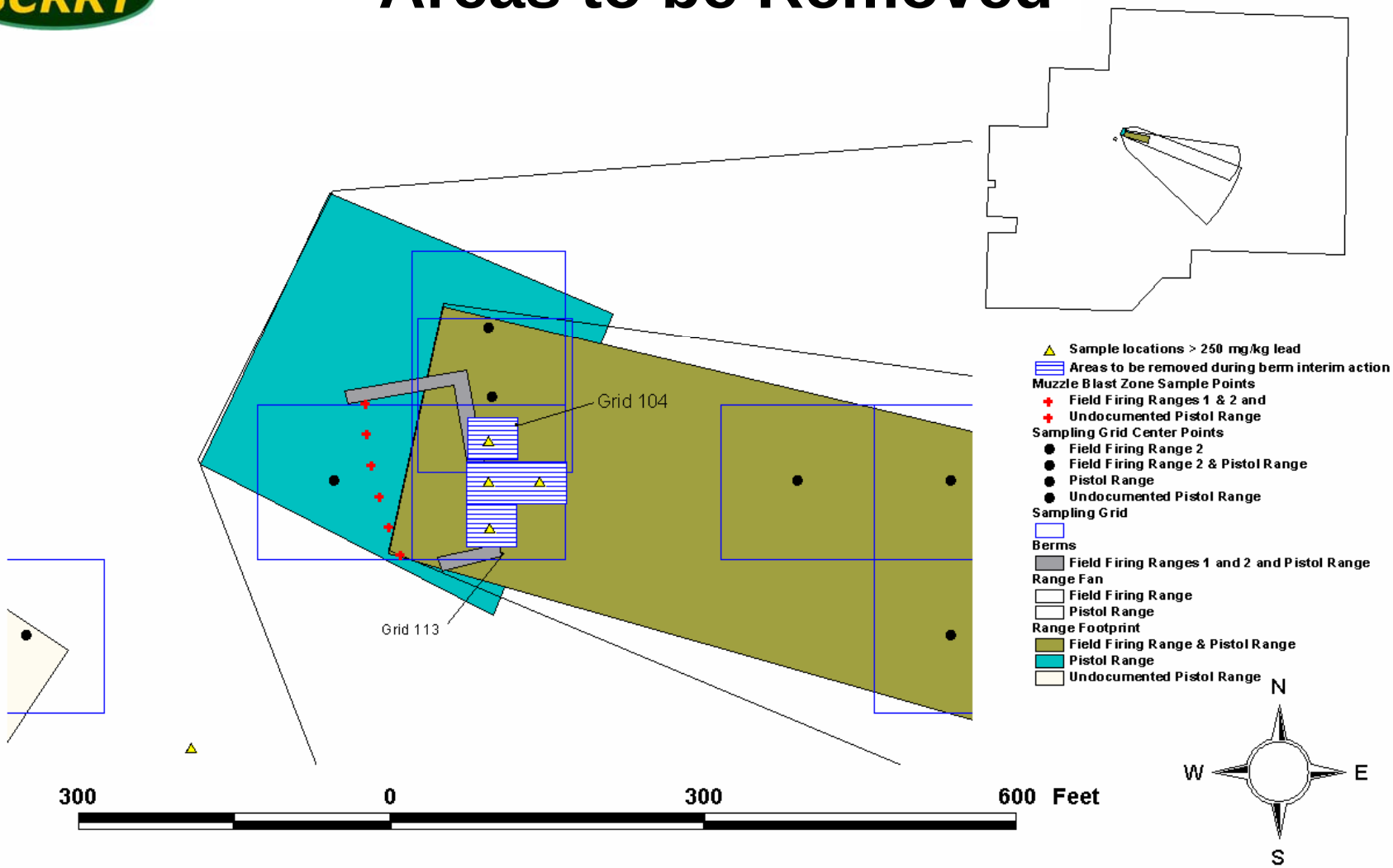
Figure 22
Field Fire Rifle Range 1 & 2
Areas to be Removed



BONNEVILLE CONSERVATION, RESTORATION & RENEWAL TEAM, LLC

BCRRT

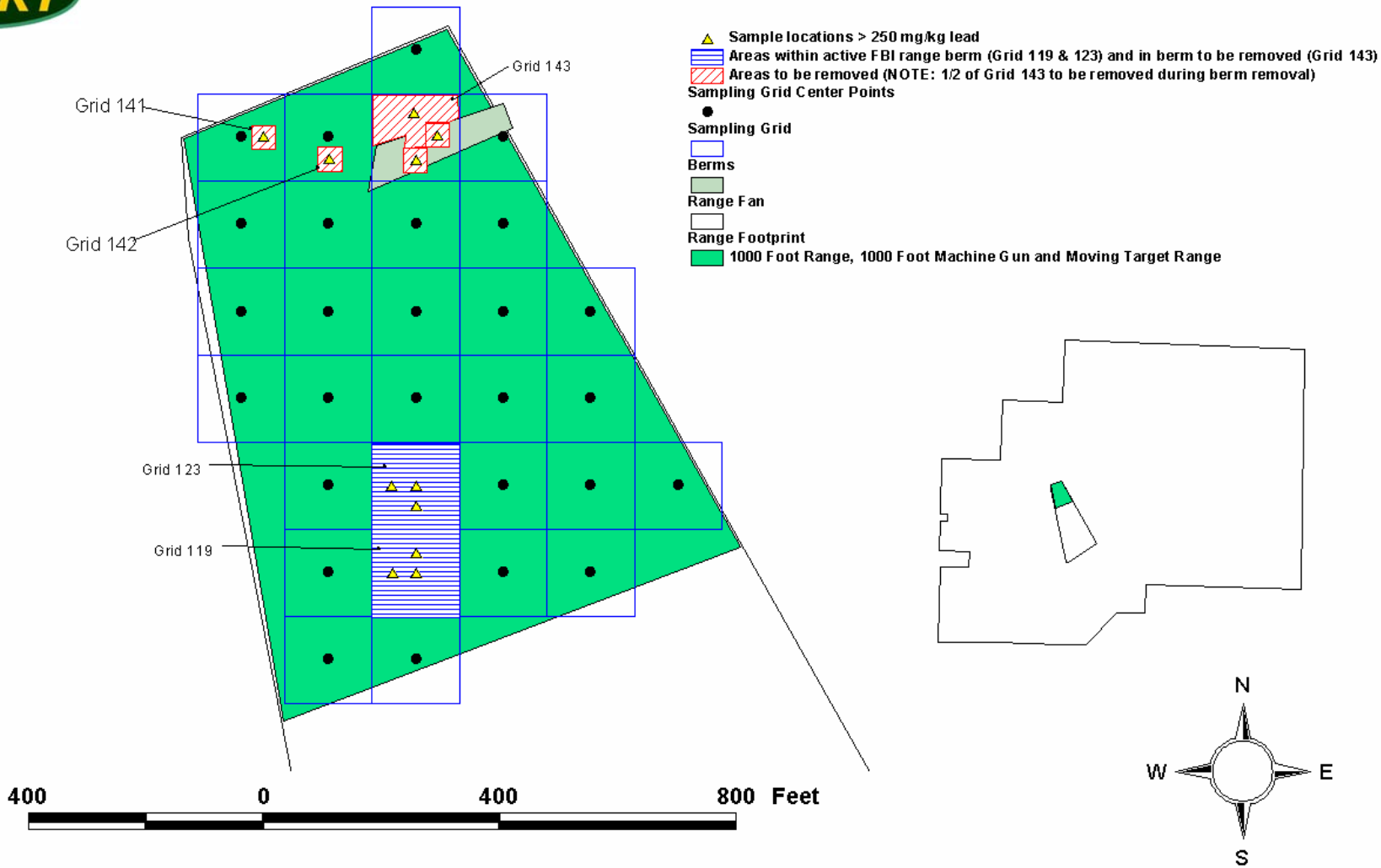
Figure 23
Field Firing Ranges & Pistol Range Areas to be Removed



BONNEVILLE CONSERVATION, RESTORATION & RENEWAL TEAM, LLC

BCRRT

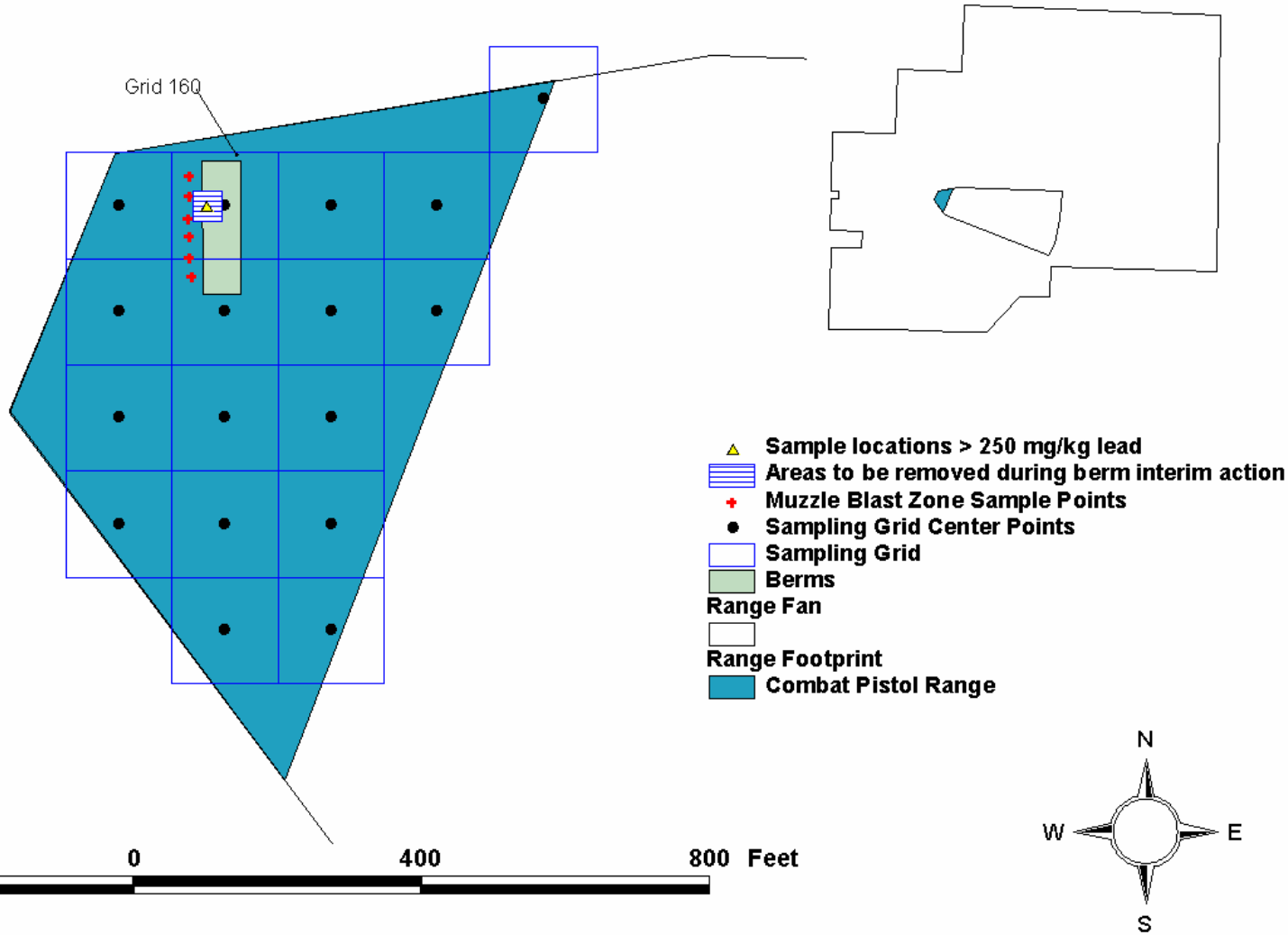
Figure 24
1000-ft Range, 1000-ft Machine Gun and Moving Target Range Areas to be Removed



BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

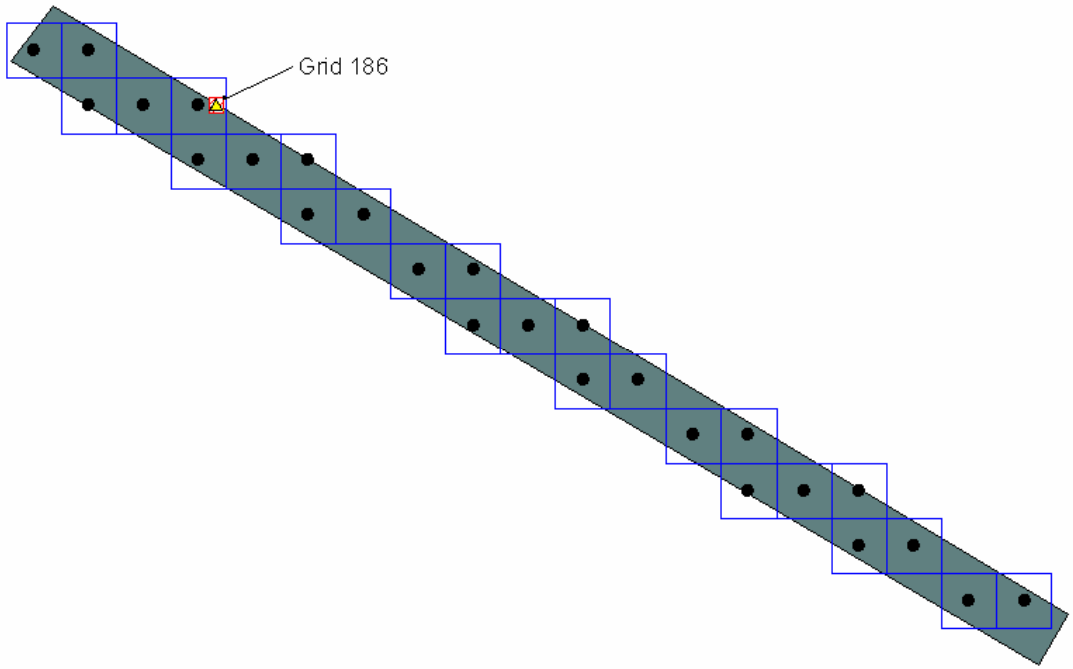
Figure 25
Combat Pistol Range
Areas to be Removed

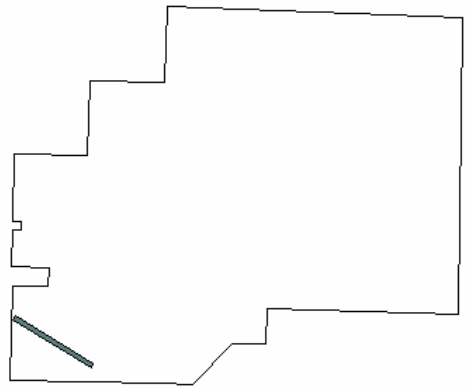


BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

BCRRT

Figure 26
Machine Gun Range





Sample locations > 250 mg/kg lead
Areas to be removed
Sampling Grid Center Points
Sampling Grid
Range Footprint
Machine Gun Range South

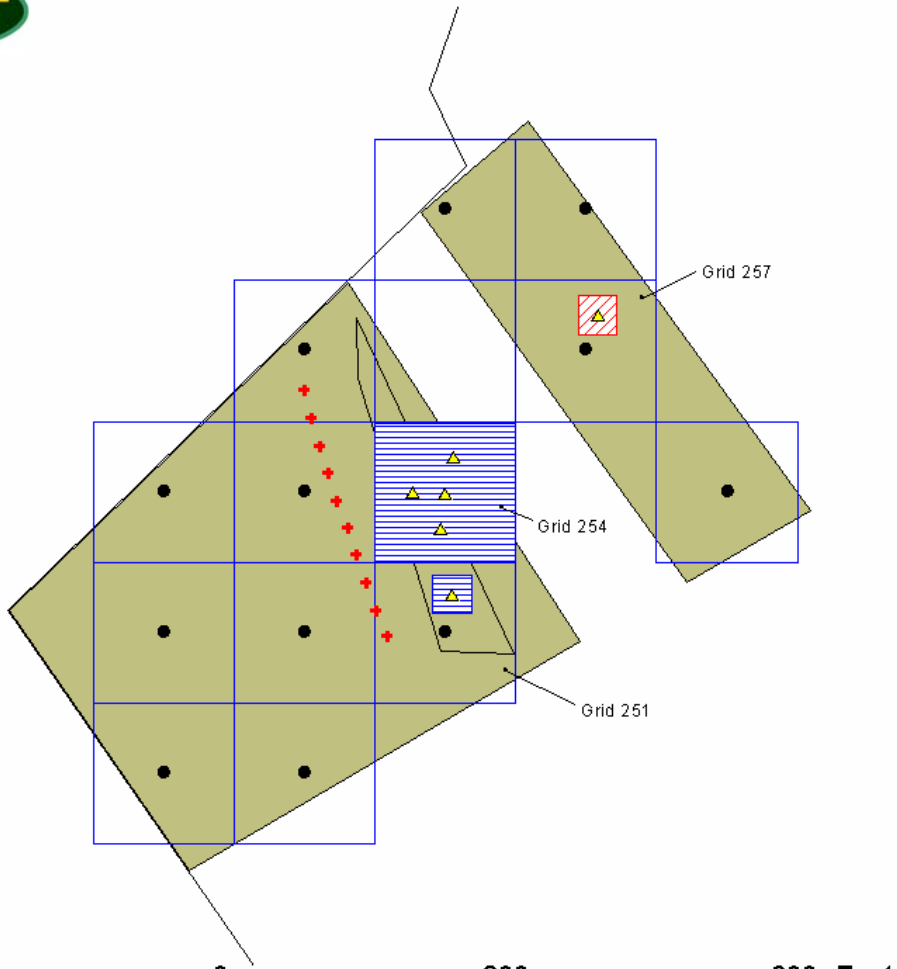
N
W
E
S

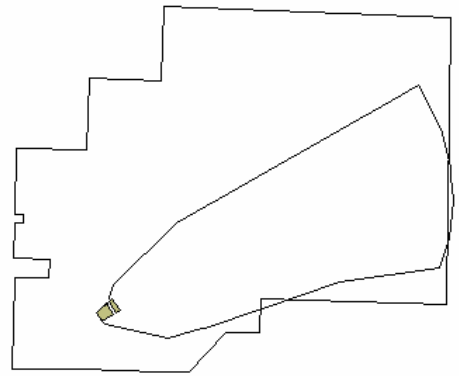
1000 0 1000 2000 Feet

BONNEVILLE
CONSERVATION,
RESTORATION &
RENEWAL
TEAM, LLC

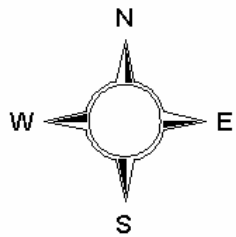
BCRRT

Figure 27
25 Meter and Machine Gun Range
Areas to be Removed





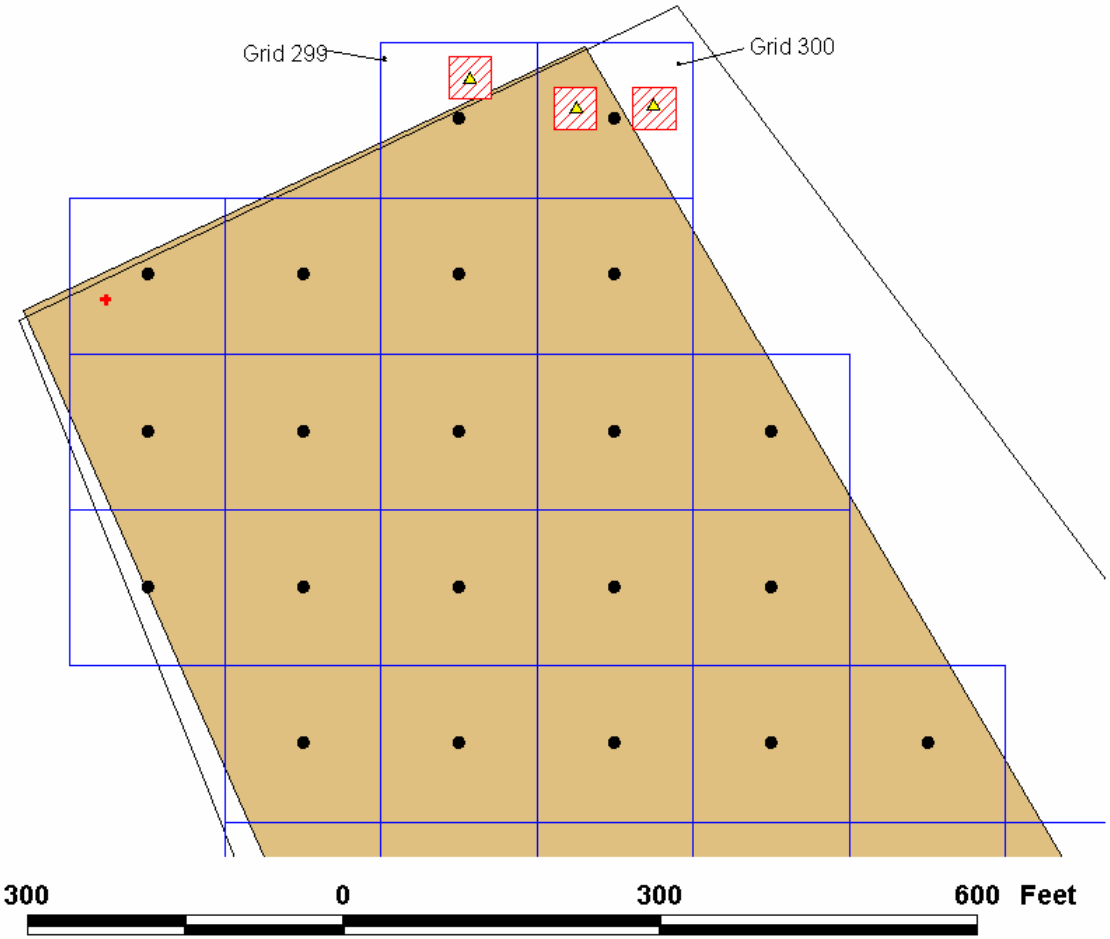
Sample locations > 250 mg/kg lead
Areas to be removed during berm interim action
Areas to be removed
Muzzle Blast Zone Sample Points
Sampling Grid Center Points
Sampling Grid
Berms
Range Fan
Range Footprint
25M Range, Machine Gun Range

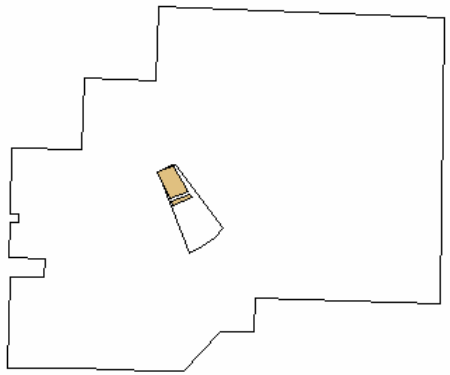


BONNEVILLE CONSERVATION, RESTORATION & RENEWAL TEAM, LLC

BCRRT

Figure 28
25M Record Fire Field Range, Field Firing Range Areas to be Removed





Sample locations > 250 mg/kg lead
Areas to be removed
Muzzle Blast Zone Sample Points
Sampling Grid Center Points
Sampling Grid
Range Fan
Range Footprint
25M Record Fire Range, Field Firing Range