The Military Munitions Response Program: A Case Study of Munitions Response Site MU732

by
Kevin Michael Limani

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Linda R. Taylor, Committee Chair

ABSTRACT

LIMANI, KEVIN. The Military Munitions Response Program – A Case Study of Munitions Response Site MU732 (Under the direction of committee chair Linda R. Taylor, PE)

Munitions Response Site (MRS) MU732 at Nellis Air Force Base, Nevada was added to the Military Munitions Response Program's inventory in 2003 due to a long history of soil contamination by military munitions. Comprehensive Site Evaluations and a Remedial Investigation conducted on the site identified soil concentrations of polycyclic aromatic hydrocarbons (PAHs) and lead hazardous to human and ecological health. A Feasibility Study was developed and identified a remedial action suitable for MRS MU732. To meet the objective of reducing risk to human and ecological health, a system of land use controls would be implemented, and the burrowing owl, a sensitive species found on site, would be relocated to a suitable site in Southern Nevada. Due to the site's remote location, physical and biological properties, and planned future use the contaminated soil at MRS MU732 would not be remediated.

BIOGRAPHY

First Lieutenant Kevin M. Limani is the Flight Commander of the Fuels Management Flight and is currently assigned to the 99th Logistics Readiness Squadron at Nellis Air Force Base, Nevada. Lieutenant Limani was born in Trenton, New Jersey and grew up in the neighboring suburb of Hamilton, New Jersey. He attended Steinert High School where he excelled at academics and participated in athletics throughout all seasons. Upon graduation in June 2006, he ranked in the top 10 of his graduating class. Lieutenant Limani participated in cross country, winter track, and was a member of the golf team in high school.

After graduating from high school, Lieutenant Limani attended Rutgers – The State University of New Jersey. His undergraduate studies were focused on atmospheric and environmental sciences. One of his key accomplishments was designing a storm water management system that could be used to protect the pristine aquifers of the New Jersey Pine Barrens. The project was chosen by his professor to be presented to the Freeholders of Stafford Township, New Jersey. In his first semester at Rutgers, Lieutenant Limani enrolled in the United States Air Force Reserve Officer Training Corps program. In August 2008, he completed Field Training at Maxwell Air Force Base, Alabama. His four years of officer training culminated in being selected as the Cadet Vice Wing Commander of Detachment 485 which consisted of 70 cadets. In May 2010, Lieutenant Limani was awarded a Bachelors of Science degree and was commissioned as a Second Lieutenant in the United States Air Force.

Upon entering active duty in November 2010, Lieutenant Limani has held multiple positions within the Logistics Readiness Squadron such as the Officer in Charge of the Vehicle Management Flight, Installation Deployment Officer, and assisted in standing up the Logistics Quality Assurance section. He currently leads the most diverse Fuels Flight in the Air Combat Command as the Flight Commander for 116 fuels personnel. Lieutenant Limani has held a council position for the installation Company Grade Officer Council and has participated in several volunteer opportunities such as Junior Achievement and Habitat for Humanity.

Lieutenant Limani graduated from Logistics Readiness Officer Basic Course with Distinguished Graduate honors. Additionally, he is one task shy of being awarded his Masters of Environmental Assessment Degree from North Carolina State University. His long-term goals are to earn a Doctorate Degree in an Environmental Sciences discipline and to become a leader for environmental sustainability in the United States military

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INTRODUCTION

The mission of the Department of Defense (DoD) is to provide the military forces needed to deter war and to protect the security of the United States of America (*Quadrennial Defense Review*, 2010). These aforementioned military forces require certain skillsets to obtain their military objectives. In order to develop these skillsets, the DoD manages an infrastructure of nearly 30 million acres of land that provides the spatial capacity to organize, train and equip their forces (*Section 313 Report*, 2007). After decades of military training, DoD properties have become riddled with unexploded ordnances[#] (UXO), discarded military munitions[*] (DMM), and munitions constituents[+] (MC) (*Section 313 Report*, 2007). In response to the environmental contamination by UXO, DMM, and MC, the DoD established the Military Munitions Response Program (MMRP) in September 2001 to manage the restoration process of military-use grounds (*Section 313 Report*, 2007).

Throughout this case study, I will thoroughly detail the MMRP from cradle to grave using munitions response site (MRS) MU732 at Nellis Air Force Base (AFB), Nevada as an example. I will differentiate DoD environmental restoration initiatives, review the MMRP process, and summarize each phase of the restoration process at MU732. Finally, I will formulate a Feasibility Study that lays out the potential remedial actions at MU732 by comparing the conditions of MU732 to other MRSs around the Air Force.

DEPARTMENT OF DEFENSE ENVIRONMENTAL RESORATION INITIATIVES

The MMRP is part of a larger DoD environmental restoration initiative, the Defense Environmental Restoration Program (DERP). The DERP was established by the Superfund Amendments and Reauthorization Act of 1986 (SARA). This program provides the funding for the cleanup of hazardous substances associated with past DoD activities at operating installations, as well as at Formerly Used Defense Sites[X] (FUDS) (*DERP, 1986*). Along with the MMRP, the Installation Restoration Plan (IRP) is captured under the DERP (*DERP, 1986*). The IRP is designed to identify, investigate, and clean up contamination associated with past DoD activities at active military installations; government-owned, contractor-operated facilities; off-site locations where contamination may have migrated; and sites that the DoD formerly owned or used (*AFI 32-7020*, 1994). To simplify, the IRP requires each service component to meet its lawful obligations to eliminate threats to public health and restore natural resources for future use (*Management Guidance for the Defense Environmental Restoration Program*, 1998). In contrast to the IRP, the MMRP focuses on the potential explosives safety, health, and environmental issues caused by past DoD munitions related activities (*Nellis AFB MMRP*, 2008).

(#) **UXO**: Military munitions that (a) have been primed, fuzed, or armed, or otherwise prepared for action; (b) have been fired, dropped, launched, projected, or placed in such a manner as constitute a hazard to operations, installations, personnel, or material and (c) remain unexploded either by malfunction, design, or any other cause.
(*) **DMM**: Military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal, but does not include UXO.
(+) **MC**: Materials originating from UXO, DMM, or other military munitions, including explosive and non-explosives and non-explosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions.
(X) **FUDS**: Sites that have been transferred from DoD control prior to October 1986.

THE CERCLA RESTORATION PROCESS

The MMRP applies the environmental restoration process set forth by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and its implementing regulation, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and in some instances, the Resources Conservation and Recovery Act (*Section 313 Report*, 2007). The following section outlines the CERCLA restoration process and highlights significant differences found within the MMRP.

CERCLA, commonly referred to as Superfund, was enacted by congress in December 1980. It gave authority to the federal government to respond directly to releases or threatened releases of hazardous substances that could endanger public health or the environment. The Environmental Protection Agency (EPA) developed standard practices to which investigators could use to evaluate the degree of harm caused by the release of hazardous substances. This restoration process contains several designed phases to assist in defining the problem, identifying extent of contamination, and developing remedial actions.

The CERCLA restoration process begins with a Preliminary Assessment (PA). This phase involves site discovery and notification to the EPA of a possible release of hazardous substances. The PA is designed to identify possible threats to human and environmental health. Under the MMRP, the program manager at an installation will identify possible sites to higher headquarters through historical reviews and initial site surveys. If a significant threat occurs, the PA will recommend a Site Inspection (SI) for further investigation.

The main objectives of a Sl include the collection of environmental samples, and identification and analysis of specific contaminants to determine whether they are being released to the environment from the site. The SI can be conducted in multiple stages. Rather than Site Investigations, the MMRP refers to similar multistage investigations as Comprehensive Site Evaluations (CSE). A CSE Phase I is analogous with the CERCLA PA, while the CSE Phase II includes a majority of the actions that occur during the SI. At the completion of the SI, the EPA decides whether the site qualifies for possible inclusion on the National Priority Listing (NPL). The NPL includes those sites that pose the most serious threats to human and environmental health. The EPA's Hazard Ranking System (HRS) evaluates the severity of each site and allows the NPL to be prioritized for the purpose of remedial action. In contrast, MMRP sites are added to an MMRP Inventory through the use of the Military Munitions Response Prioritization Protocol (hereafter, Protocol). Once a site is added to the NPL or the MMRP Inventory a remedial investigation/feasibility study (RI/FS) is performed on the site.

The RI serves as the mechanism for collecting data to characterize site conditions, determine the nature of the contamination, and assess risk to human health and the environment. Under CERCLA, the Agency for Toxic Substances and Disease Registry must conduct a health assessment for each site found on the NPL. For sites within the MMRP Inventory, health assessments are typically conducted by a contracted entity. The purpose of the health assessment is to assist in determining whether current or potential risk to human health exists at a site and whether additional information on human exposure is needed.

The FS is the mechanism for the development and detailed evaluation of alternative remedial actions. Following the analysis of remedial activities, a Report of Decision is published which states the restoration technologies that will be used on the site. The majority of the physical restoration happens during the Remedial Design and Remedial Action steps. A site is delisted from the NPL once appropriate remedial levels have been achieved. Finally, the EPA or the military installation will work with the stakeholders to return the site to safe and productive use without adversely affecting the remedy.

THE MILITARY MUNITIONS RESPONSE PROGRAM

The MMRP ultimately falls under the responsibility of the DoD but is executed and centrally managed by each service component (*Air Force MMRP*, 2009). For example, each Air Force installation has a MMRP Program Manager who works closely with the Regional-Project Management Office at the Air Force Center for Engineering and the Environment. The MMRP is governed by both federal and state environmental legislation, so the Program Manager also works closely with his or her respective state's environmental agency (*Air Force MMRP*, 2009).

The initial MMRP Inventory was published in May 2003 (*Prioritization Protocol Meeting with the States, 2003*). The Protocol was implemented in October 2005 which prioritized the existing MMRP Inventory (*Federal Register Vol. 70, No. 192*., 2005). The establishment of the protocol was necessary to manage the growing inventory due to varying degrees of contamination as well as fiscal and manpower restraints (*Section 313 Report,* 2007). Similar to the HRS, the protocol is a process of ranking the severity of contamination of each MRS based on three factors: explosive, chemical and relative risk (*Section 313 Report*, 2007). For instance, the Protocol considers the following elements of an MRS:

- Presence of known or suspected unexploded ordnance, discarded military munitions, or munitions constituents
- Types of munitions or munitions constituents
- Presence/effectiveness of public access controls
- Potential/evidence of direct human contact
- Status of any response actions
- Date for transfer from military control
- Extent of documented incidents
- Potential for drinking water contamination or release into the air
- Potential for damage to natural resources

In addition, "Risk-plus" factors, such as regulator and stakeholder concerns, mission-driven requirements, cultural and social factors, economic factors and reasonably anticipated future land use are applied when prioritizing each MRS (*MRSPP Review & Update Brief*, 2011).

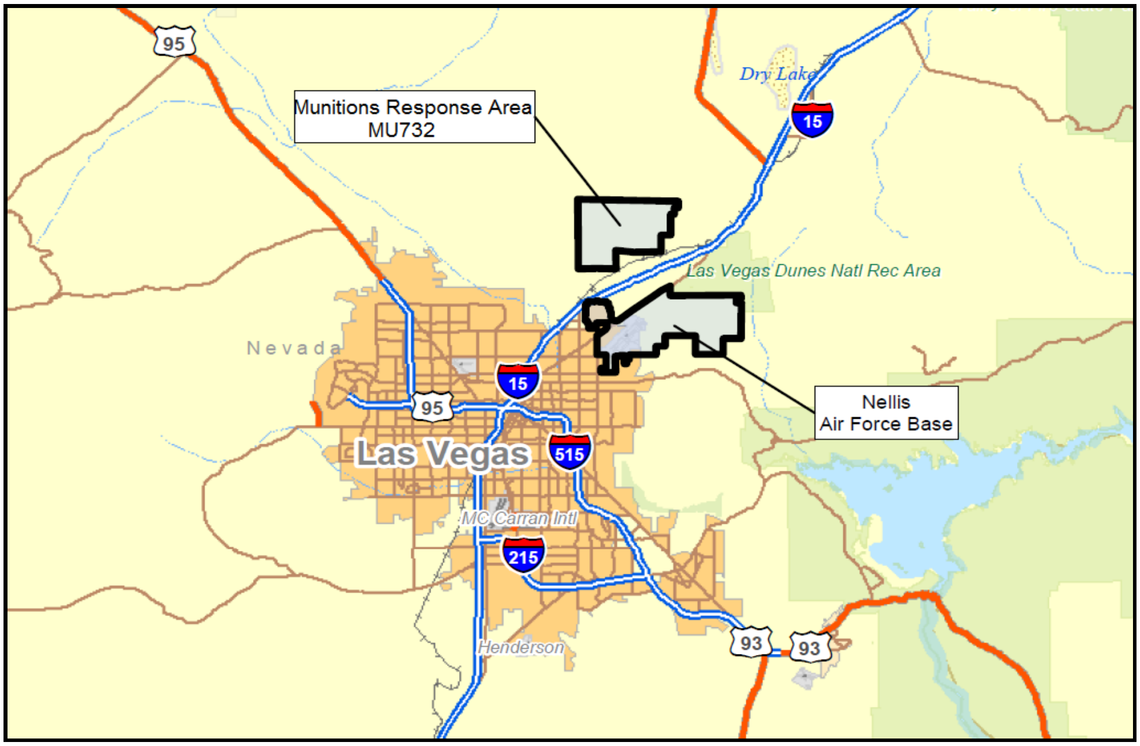
As of 2010, there were 3,783 sites in the DoD MRS Inventory (*Defense Environmental Programs Annual Report to Congress*, 2009). The Air Force has identified 505 MRSs totaling 479,435 acres at 65 installations in 32 states (*Air Force MMRP Brief*, 2009). Of the 505 MRSs, 124 have been closed (no-further action required) totaling 167,067 acres (*Air Force MMRP Brief*, 2009). The majority of Air Force MRSs have been identified as small arms ranges and open burn/open disposal (OB/OD) pits (*Air Force MMRP Brief*, 2009). Restoration of small arms ranges, which make up 40% of the Air Force's MRS inventory, require less time and money to achieve closure (*Air Force MMRP Brief*, 2009). This scale of restoration typically involves the surface clearance of non-hazardous inert fragments and clutter items. The Air Force has found that large munitions and mixed use ranges will drive the long-term program. These types of sites are associated with bombing ranges, air-to-ground ranges and artillery ranges. The goal of the Air Force is to have 95% of MMRP sites at active installations closed by the end of Fiscal Year 2021 (*MRSPP Review & Update Brief*, 2011).

NELLIS AFB AND MRA MU732

Nellis AFB is located approximately eight miles northeast of downtown Las Vegas in North Las Vegas, Clark County, Nevada. There are three Munitions Response Areas[$] (MRA) on the installation, MU732, XU741 and TM742, totaling 4,400 acres which were derived from multiple historic military ranges (URS, 2006). In 1941, the Flexible Gunnery School (47,000 acres) was established for the use of small arms, air-to-ground, ground-to-air, air-to-air, bombing, rocketry and demolition training. Today, 7,000 acres are still used for small arms training and 36,000 acres have been returned to various state and federal entities (URS, 2006). MRA MU732 has been divided into 4 MRSs: MU732, MU732a, MU732b and MU732c. There are two distinct areas within the 419 acre MRS MU732: a historic shotgun firing range and a training and maneuver range. The training and maneuver range consists of a complex of gravel roads that was used as a training area for small arms mounted onto vehicles. MRA MU732 is expected to remain under the control of the DoD for the foreseeable future. The geographic location of Nellis AFB and MRA MU732 is depicted in Figure 1.

($) **MRA**: DoD properties that are suspected to contain DMM, UXO or MC. An MRA may be subdivided into multiple MRSs to allow for more efficient characterization so that munitions responses specific to local conditions can be conducted.

Figure 1: Nellis AFB and MRA MU732



CSE PHASE I

The first stage of the restoration process at MU732 began in 2006 with a CSE Phase I conducted by URS Group, a contracted organization. The investigators reviewed historical records from on-site and off-site data repositories and conducted interviews with persons knowledgeable about Nellis AFB. The Phase I was capped off by a visual survey of MU732 to identify physical evidence of contamination.

The first official report recognizing the existence of munitions and explosives of concern (MEC) was completed in March of 1972. The Range Clearance Report was drafted by the 2701st Explosive Ordnance Disposal (EOD) Squadron, Hill AFB, Utah. The EOD team located, identified, and disposed of following MEC items:

- 2.75 rocket motors
- M23 Igniters with M173 fuzes
- M23 Igniter without fuze
- Miscellaneous small arms up to .50 caliber
- Small amount of explosives residues

A second range clearance was performed by Nellis AFB EOD in 1995. During the clearance, the team located, identified, and disposed of the following items:

- (BDU)-33/B Practice bomb
- MK 106 practice bomb
- Practice MK 82 Mod 0 bomb
- M117 inert bomb
- MK 42 Mod 1 rocket motor
- M229 2.75 inch High Explosive (HE) rocket warhead
- MK 1 Mod 3 inert rocket warhead
- AN-M14 thermite grenade
- .50 caliber ball ammunition
- 20mm HE incendiary projectile

During the visual survey, the investigators identified .30 and .50 caliber projectiles, cartridge casings, 12 gauge shotgun shells and lead shot, clay pigeon debris, berms, concrete firing points, machine-gun mounting poles, shotgun shell burn pits and target debris. The identification of MEC is important to understand the primary composition, or MC, of each item. For instance, the MCs for bombs and bomb fuzes are heavy metals, volatile organic compounds, and semi-volatile organic compounds.

Furthermore, a review of Nellis' Integrated Natural Resources Management Plan indicated the possible presence of special-status plants and animals on Nellis AFB. Special status includes State- and Federally-listed threatened or endangered species, species of concern, and species considered sensitive or special by the state. Eight animal species and one plant species listed as threatened or endangered by the State or Federal governments have the potential to be present in southern Nevada. Based on the habitat requirements or preferences of the threatened and endangered species, only the desert tortoise is likely to be present at MU732. In addition, one sensitive species, the western burrowing owl, has the potential to inhabit MU732. The burrowing owl has been listed as a sensitive species by the Nevada Bureau of Land Management, but is not legally protected like the desert tortoise (BLM, 2011). The existence of such species, as well as possible human receptors, can affect prioritization of the site and potential remedial actions.

The team identified Air Force personnel and unauthorized persons that trespass onto the site as possible human receptors. Access to MU732 for Air Force personnel was and continues to be limited to individuals performing ground maintenance, ecological surveys or security. Based on the receptors, environmental setting, and suspected chemicals of concern, the team completed exposure pathway analyses. Complete pathways indicate the possibility of ingestion, inhalation or dermal absorption by the receptors which can lead to harmful health effects. They found that exposure pathways for ground water and surface water were incomplete for humans and ecological receptors; shallow aquifers in the region are not utilized for potable water or irrigation, and significant bodies of surface water do not exist at Nellis AFB. The team identified a potentially complete exposure pathway for MC-impacted soil at the site. Due to the fact that sensitive munitions, including HE munitions and thermite grenades, were documented during previous surface clearance activities the investigators assessed MU732 as a high priority and recommended a CSE Phase II be conducted.

CSE PHASE II

The CSE Phase II was completed by Bay West, Inc. in 2010. The team conducted a site survey to evaluate the extent of MEC and collected surface and subsurface soil samples from areas with significant evidence of MEC for worse-case MC analysis.

During the site survey, the investigators detected two primary MEC items, spent ammunition cartridges from small arms and clay target debris. The primary MC associated with small arms ammunition are heavy metals, primarily lead. Lead shot, small lead pallets ranging in size from 1 to 15 millimeters, were the original and most common form of shotgun ammunition. The surveyors noted a significant amount of lead shot on the soil surface. Clay targets are typically composed of limestone (70%) and a coal tar binding material (Lobb, 2006). This material can, especially in older manufactured models, contain polycyclic aromatic hydrocarbons (PAHs) at concentrations ranging from 3,000 to 40,000 mg/kg per target (Lobb, 2006). Table 1 illustrates the typical PAH content in clay targets. The Department of Health and Human Services has determined the following PAHs may reasonably be expected to be carcinogens: benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene and idenol(1,2,3-cd)pyrene. Based on the primary MEC items, the investigators did not anticipate MC associated with explosive hazards to be present. The investigators conducted surface and subsurface soil sampling for analysis of lead and PAHs.

Table 1: Typical PAH Content of Clay Targets (Lobb, 2006)

PAH	Concentrations (mg/kg)	PAH	Concentrations (mg/kg)
Acenaphthene	257	Benzo(a)anthracene	1736
Fluorene	370	Chrysene	1764
Phenanthrene	1781	Benzo(b)fluoranthene	1852
Anthracene	712	Benzo(k)fluoranthene	832
Fluoranthene	2881	Benzo(a)pyrene	1764
Pyrene	2058	Dibenzo(a,h)anthracene	487
Benzo(g,h,i)perylene	1543		

A total of 29 surface soil samples and 24 subsurface soil samples were analyzed for lead by way of off-site laboratory methods. Lead was detected above the background lead levels for a majority of the samples. Additionally, lead was observed above ecological and human health screening criteria in one sample. Forty-three surface soil samples and 14 subsurface soil samples were analyzed for PAHs by way of off-site laboratory methods. Table 2 illustrates the results of the PAH analysis. In summary, 7 PAHs exceeded human health screening criteria and 9 PAHs exceeded ecological screening criteria.

The extent of PAH contamination was of particular interest to the investigators. PAHs were found in areas with significant clay target debris as well as near areas that lacked the presence of clay target debris, sometimes in high concentrations. This was attributed to PAH migration through overland transport, primarily during rain events. However, PAHs extended radially outward from the clay target source, and were not biased to the topographically downslope areas. Therefore, some mechanical distribution of the PAHs may have occurred. PAHs above screening levels extended as far as 200 feet from the areas where clay targets were observed. However, vertical migration of PAHs through the soil column occurred to a limited extent. On average, there was a 65.8% reduction in the concentration of total PAHs from the surface soil samples to the subsurface soil samples, which were collected at 0.5-1.0 feet below ground surface. Based on these results, it was anticipated that the PAHs are limited to the top 1.5-2 feet below ground surface. Future vertical migration of PAHs is unlikely to occur due to the physical properties of PAHs and the dry climate of the region. In conclusion, the team recommended further evaluation of lead and PAHs in surface and subsurface soil at MU732 through a RI.

Table 2: PAH Sampling Results

Shotgun Firing Range - MU732				
PAH	**Detected Concentrations**	**Residential Screening Level**	**Industrial Screening Level**	**Ecological Screening Level**
Benzo(a)anthracene	0.015-33 mg/kg	0.15 mg/kg	2.1 mg/kg	1.1 mg/kg
Benzo(a)pyrene	0.024-48 mg/kg	0.015 mg/kg	0.21 mg/kg	1.1 mg/kg
Benzo(b)fluoranthene	0.05-91 mg/kg	0.15 mg/kg	2.1 mg/kg	1.1 mg/kg
Benzo(g,h,i)perylene	0.025-37 mg/kg	Not Available	Not Available	1.1 mg/kg
Chrysene	0.02-41 mg/kg	15mg/kg	210 mg/kg	1.1 mg/kg
Dibenzo(a,h)anthracene	0.0065-11 mg/kg	0.015 mg/kg	0.21 mg/kg	1.1 mg/kg
Fluoranthene	0.027-55 mg/kg	2300 mg/kg	22000 mg/kg	1.1 mg/kg
Ideno(1,2,3-cd)pyrene	0.021-34 mg/kg	0.15 mg/kg	2.1 mg/kg	1.1 mg/kg
Pyrene	0.026-50 mg/kg	1700 mg/kg	17000 mg/kg	1.1 mg/kg
Training and Maneuver Area - MU732				
PAH	**Detected Concentrations**	**Residential Screening Level**	**Industrial Screening Level**	**Ecological Screening Level**
Benzo(a)anthracene	0.047-46 mg/kg	0.15 mg/kg	2.1 mg/kg	1.1 mg/kg
Benzo(a)pyrene	0.066-65 mg/kg	0.015 mg/kg	0.21 mg/kg	1.1 mg/kg
Benzo(b)fluoranthene	0.14-120 mg/kg	0.15 mg/kg	2.1 mg/kg	1.1 mg/kg
Benzo(g,h,i)perylene	0.059-50 mg/kg	Not Available	Not Available	1.1 mg/kg
Chrysene	0.054-49 mg/kg	15mg/kg	210 mg/kg	1.1 mg/kg
Dibenzo(a,h)anthracene	0.016-15 mg/kg	0.015 mg/kg	0.21 mg/kg	1.1 mg/kg
Fluoranthene	0.087-61 mg/kg	2300 mg/kg	22000 mg/kg	1.1 mg/kg
Ideno(1,2,3-cd)pyrene	0.055-47 mg/kg	0.15 mg/kg	2.1 mg/kg	1.1 mg/kg
Pyrene	0.079-58 mg/kg	1700 mg/kg	17000 mg/kg	1.1 mg/kg

REMEDIAL INVESTIGATION

A RI was conducted by URS in 2012. The primary objectives were to refine the boundaries of the site, characterize the nature and extent of contamination, and assess human health and ecological risk. During a site reconnaissance, evidence of on-site OB/OD was observed. As a result, the characterization of the nature and extent of MEC in the form of dioxins and furans was added as an objective of the RI.

Extensive sampling for lead, PAHs, dioxins and furans was conducted to determine the extent of contamination. A total of 632 soil samples were collected to determine the vertical and horizontal migration of lead, PAH, dioxins and furans. The results of the PAH analysis are shown in Table 3 which lists the PAHs that exceeded the human health and ecological screening criteria. Of the 212 subsurface soil samples collected for PAH analysis, PAHs were detected in 191 samples. Three samples collected at the southern boundary of MU732 indicated the presence of PAHs. Although sampling stopped at the boundary, it is recommended that further sampling and analysis should be completed during the FS to address this data gap and determine the extent of downstream, off-site migration. Lead was detected in all 345 samples. Thirty-four samples had lead concentrations above the human health screening criteria and 170 samples had lead concentrations above the ecological screening criteria. Of the 32 subsurface soil samples for lead analysis, lead was detected in all 32 samples but no samples had lead concentrations above the human health screening criteria. Of the 16 surface soil samples collected for dioxin and furan analysis, dioxins and furans were detected in 13 samples but were found to be below both the human health and ecological screening levels.

Upon completion of the sampling analysis, the investigators completed a human and ecological risk assessment. The purpose of the risk assessments was to characterize the potential for MC exposure to relevant human and ecological receptors at MU732. This was done by creating a Conceptual Site Model to provide a framework for problem definition, identification of exposure pathways, identification of data needed to evaluate potential exposure pathways, and assist in drafting effective cleanup actions. The most likely potential exposure pathway was determined to be from direct contact with surface soil, resulting in incidental ingestion, dermal absorption of chemicals, or inhalation of particulates from soil by site workers, AF personnel and trespassers. Ecological receptors may be exposed through direct contact with soil, or may be indirectly exposed via food chain exposures and incidental ingestion of soils while foraging. The ecological health assessment determined the burrowing owl was the only at-risk species at MU732 for exposure to lead and PAHs. The Conceptual Site Model assists in developing Remedial Action Objectives (RAOs) and General Response Actions (GRAs) during the FS portion of the restoration process.

Finally, the investigators recommended MU732 for a FS with the objectives of reducing the quantity of MEC, MC and munitions-related contamination, reducing the number of receptors, and reducing the potential for interaction between receptors and MEC, MC and munitions-related contamination. MU732 was assigned with a priority rating of 3, where a rating of 1 indicated the highest potential hazard and a rating of 8 indicates the lowest potential hazard.

Table 3: PAHs Exceeding Human Health and Ecological Screening Criteria

Exceedance of Human Health Screening Criteria - Surface Soil		Exceedance of Human Health Screening Criteria - Subsurface Soil	
PAH	**Detected Concentrations (mg/kg)**	**PAH**	**Detected Concentrations (mg/kg)**
Benzo(a)anthracene	0.16 - 520	Benzo(a)anthracene	0.17 - 47
Benzo(a)pyrene	0.041 - 420	Benzo(a)pyrene	0.042 - 43
Benzo(b)fluoranthene	0.16 - 770	Benzo(b)fluoranthene	0.16 - 93
Benzo(k)fluoranthene	1.6 - 880	Benzo(k)fluoranthene	1.6 - 82
Chrysene	16 - 560	Chrysene	18 - 41
Dibenzo(a,h)anthracene	0.016 - 85	Dibenzo(a,h)anthracene	0.016 - 10
Indeno(1,2,3-cd)pyrene	0.16 - 360	Indeno(1,2,3-cd)pyrene	0.17 - 31
Naphthalene	3.8 - 34		
Exceedance of Ecological Screening Criteria - Surface Soil		**Exceedance of Ecological Screening Criteria - Subsurface Soil**	
PAH	**Detected Concentrations (mg/kg)**	**PAH**	**Detected Concentrations (mg/kg)**
Anthracene	32 - 45	Benzo(a)anthracene	1.2 - 47
Benzo(a)anthracene	1.3 - 520	Benzo(a)pyrene	1.2 - 43
Benzo(a)pyrene	1.2 - 420	Benzo(b)fluoranthene	1.2 - 93
Benzo(b)fluoranthene	1.5 - 770	Benzo(g,h,i)perylene	1.2 - 32
Benzo(g,h,i)perylene	1.3 - 280	Benzo(k)fluoranthene	1.2 - 82
Benzo(k)fluoranthene	1.2 - 880	Chrysene	1.2 - 82
Chrysene	1.2 - 560	Dibenzo(a,h)anthracene	1.6 - 10
Dibenzo(a,h)anthracene	1.2 - 85	Fluoranthene	1.2 - 68
Fluoranthene	1.3 - 570	Indeno(1,2,3-cd)pyrene	1.2 - 31
Indeno(1,2,3-cd)pyrene	1.2 - 360	Phenanthrene	34
Naphthalene	34	Pyrene	1.2 - 58
Phenanthrene	32 - 190		
Pyrene	1.2 - 670		

FEASIBILITY STUDY

Within the following section, I will propose a FS for MRS MU732. The official FS for MU732 is scheduled to be conducted by January 2014. I will construct the FS based on the reports provided above as well as compare proposed remedial actions to two additional Air Force MRSs (MU732c at Nellis AFB and SWMU 67 at MacDill AFB, Florida). In general, a FS contains a definition of the problem, identification of Applicable or Relevant and Appropriate Requirements (ARARs), development of RAOs and GRAs, identification of technologies and process options, screening of technologies and process options and the development of relevant remedial alternatives.

The first step to developing corrective measures is to accurately define the problem. Based on information provided by the CSE Phase I, Phase II and RI, the site exhibits soil concentrations of PAHs and lead that exceed human and ecological health criteria. The contamination is widespread throughout the 400 acre site and there is a potential occurrence of off-site migration. In addition to PAH and lead contamination, MEC have been observed on the site as recently as the RI. The RI identified site workers, Air Force personnel and the burrowing owl as potential receptors.

Future remedial actions and site conditions must comply with federal and state environmental legislation. Since it is unlikely that remedial actions will remove 100 percent of the contamination at a site, CERCLA requires that in order for any hazardous substance or pollutant to remain on a site it must meet certain regulatory standards that have been identified as ARARs. ARARs include standards, requirements, criteria, or limitations established under federal environmental law or any more stringent standards, requirements, criteria, or limitations promulgated in accordance with a state environmental statute. ARARs are classified into three categories: chemical-specific, location-specific, and action-specific. Based on the chemicals present, locations of future remedies, and the potential remedies themselves, the following are considered to be ARARs for MU732:

Federal

- 40 CFR 300, National Oil and Hazardous Substances Pollution Contingency Plan

- 50 CFR 424, Listing Endangered or Threatened Species and Designating Critical Habitat

State

- Disposal of Solid Waste
- Disposal of Hazardous Waste
- Recycling
- Voluntary Cleanup

The next step is to formulate RAOs for future corrective measures. RAOs specify the contaminants and media of interest, exposure pathways, and preliminary remediation goals that permit a range of alternatives to be developed. The following RAOs were developed for MU732:

Remedial Action Objective 1: Reduce or eliminate explosive safety hazards to human and ecological receptors associated with potential MEC.

Remedial Action Objective 2: Prevent human exposure to lead in soil at unacceptable levels of risk.

Remedial Action Objective 3: Prevent human exposure to PAHs in soil at unacceptable levels of risk.

Remedial Action Objective 4: Prevent burrowing owl exposure to lead in soil at unacceptable levels of risk.

Remedial Action Objective 5: Prevent burrowing owl exposure to PAHs in soil at unacceptable levels of risk.

Remedial actions are first introduced through the development of GRAs. GRAs are moderately-specific actions intended to satisfy the RAOs. The GRAs potentially applicable for satisfying each RAO are listed in Table 4. The GRAs were chosen based on personal knowledge of the chemicals of concern and remedial technologies, comparable site conditions of other Air Force MRSs and information gathered from the Federal Remediation Technologies Roundtable (FRTR).

Table 4: General Response Actions

RAO	General Response Action
RAO 1	MEC Removal
	Demolition
	Disposal
RAO 2	Land Use Controls (LUCs)
	In-Situ Physical/Chemical Treatment
	Ex-Situ Physical/Chemical Treatment (assuming excavation)
	Excavation and Off-Site Disposal
RAO 3	LUCs
	In-Situ Biological Treatment
	In-Situ Physical/Chemical Treatment
	Ex-Situ Physical/Chemical Treatment (assuming excavation)
	Excavation and Off-Site Disposal
RAO 4	In-Situ Physical/Chemical Treatment
	Ex-Situ Physical/Chemical Treatment (assuming excavation and relocation of burrowing owl)
	Excavation and Off-Site Disposal (assuming relocation of burrowing owl)
	Relocation of Burrowing Owl Supplemented by Site Surveys
RAO 5	In-Situ Biological Treatment
	In-Situ Physical/Chemical Treatment
	Ex-Situ Physical/Chemical Treatment (assuming excavation and relocation of burrowing owl)
	Excavation and Off-Site Disposal (assuming relocation of burrowing owl)
	Relocation of burrowing owl Supplemented by Site Surveys
	No Action (Required for comparison with other alternatives)

As the FS progresses, the GRAs are further specified by introducing remedial technologies. The remedial technologies are methods by which a GRA may be undertaken. Appendix A illustrates the identification and initial screening of remedial technologies. As an initial screening, remedial technologies were evaluated based on their implementability and general applicability to the conditions at MU732. Again, the remedial technologies were chosen based on personal knowledge, comparable site conditions to other Air Force MRSs and information gathered from the FRTR.

Each remedial technology represented in Appendix A has the ability to reduce or eliminate explosive hazards, PAHs or lead with a varying degree of effectiveness and ease. For instance, the excavation of one foot of soil from a 400 acre site is costly and environmentally intrusive. In order to develop realistic remedial alternatives, the retained technologies were further evaluated with respect to three evaluation criteria: effectiveness, implementability and cost. The effectiveness of a technology is based on its ability to achieve design goals, potential adverse environmental impacts during implementation, and how proven the technology option is with respect to addressing conditions at the site. The implementability of a process is based on factors such as safety, regulatory and public support, compatibility with planned land uses and availability of material and equipment. The cost criterion is based on the total cost of a process option, including capital costs and long-term monitoring. Costs were estimated based on the FRTR's treatment technologies screening matrix. Table 5 lists the retained technologies from the detailed screening process. Appendix B illustrates the entire detailed screening of technologies and process options.

Table 5: Remedial Technologies and Process Options

General Response Action	Remedial Technology	RAO 1	RAO 2	ROA 3	RAO 4	RAO 5
MEC Removal	Manual Removal - Surface Clearance	X				
Demolition	Demilitarization	X				
Land Use Controls (LUCs)	Fencing	X	X	X		
	Signage	X	X	X		
	Administrative Controls	X	X	X		
Relocation of Burrowing Owl Supplemented by Site Surveys	Specie Retrieval, Relocation and Site Surveys				X	X
No Action	N/A					

In order to satisfy all RAOs, multiple GRAs were combined to develop a suitable remediation strategy. The retained technologies and process options from the detailed screening process were used to develop remedial alternatives. To address the Remedial Action Objectives developed for MU732, the following alternatives were developed:

Alternative 1 – No Action

The no action alternative assumes that no actions would be taken regarding MEC or MC at MU732. No institutional or engineering LUCs would be implemented. This method requires no implementation and would have no capital or operations and maintenance costs. This alternative is required for baseline comparison purposes.

Alternative 2 – LUCs/Relocation of Burrowing Owl Supplemented by Site Surveys

LUCs are institutional or engineering controls to protect human health and the environment by controlling access and exposure to contaminants or hazards; LUCs would be kept in place indefinitely. LUCs for MU732 would restrict access to the areas and would prohibit construction and instructive activities within the MRS. Administrative controls would consist of restrictions on land use and educations programs to inform potential receptors of the risk. Engineering controls would consist of the installation of signage every 100 feet at access points along the perimeter of the MRS to inform receptors of the potential presence of MEC. Aviary experts would retrieve and relocate burrowing owls to a suitable destination in Southern Nevada. Owl burrows would be destroyed to deter future occupation. Semi-annual site surveys would be conducted to document the occupation by burrowing owls. Any owls found on the site would be relocated.

Alternative 3 – MEC Removal/LUCs/ Relocation of Burrowing Owl Supplemented by Site Surveys

Site surveyors and UXO technicians would locate MEC at MU732. The surveyors would utilize detection technologies such as magnetometers to locate subsurface MEC. Once found, the MEC would be manually removed by Nellis EOD personnel and demilitarized. The MEC scraps would be disposed of internally by Nellis EOD personnel. LUCs are institutional or engineering controls to protect human health and the environment by controlling access and exposure to contaminants or hazards. LUCs would be kept in place indefinitely. LUCs for MU732 would restrict access to the areas and would prohibit construction and instructive activities within the MRS. Administrative controls would consist of restrictions on land use and educations programs to inform potential receptors of the risk. Engineering controls would consist of the installation of signage every 100 feet at access points along the perimeter of the MRS to inform potential receptors of the potential presence of MEC. Aviary experts would retrieve and relocate burrowing owls to a suitable destination in Southern Nevada. Owl burrows would be destroyed to deter future occupation.

Semi-annual site surveys would be conducted to document the occupation by burrowing owls. Any owls found on the site would be relocated.

Table 6: Remedial Alternatives Development Summary

General Response Action	Remedial Technology	Alternative 1	Alternative 2	Alternative 3
MEC Removal	Manual Removal - Surface Clearance			**X**
Demolition	Demilitarization			**X**
Land Use Controls (LUCs)	Fencing		**X**	**X**
	Signage		**X**	**X**
	Administrative Controls		**X**	**X**
Relocation of Burrowing Owl Supplemented by Site Surveys	Specie Retrieval, Relocation and Site Surveys		**X**	**X**
No Action	N/A	**X**		
Alternative Carried Forward to Detailed Analysis?		**X**	**X**	**X**

This next section presents the analysis of each alternative with respect to the evaluation criteria prescribed by the NCP (40 CFR 300.430) and the US Army MMRP Munitions Response RI/FS Guidance (U.S. Army 2009). The nine criteria identified by the NCP and U.S. Army MMRP guidance are divided into three functional categories: threshold criteria, primary balancing criteria, and modifying criteria. Threshold criteria are requirements each alternative must meet or have specifically waived to be eligible for selection.

Overall Protection of Human Health and the Environment - Addresses whether a specific alternative will achieve adequate protection and describes how MEC at the MRS will be eliminated, reduced, or controlled through removal and/or LUCs.

Compliance with ARARs - Addresses whether a remedial alternative meets all selected federal and state environmental statutes and regulations.

Primary balancing criteria are those that, for the basis for comparison among the alternatives, meet the threshold criteria. Primary balancing criteria consist of the following:

Long-Term Effectiveness and Permanence - Addresses the ability of a remedial alternative to maintain reliable protection of human health and the environment over time, and considers the magnitude of residual risk/hazard, the adequacy of the response in limiting the risk/hazard, and whether LUCs and/or long-term management are required.

Reduction of Toxicity, Mobility or Volume (TMV) through Treatment - Addresses the preference for remedial actions that use treatment technologies that permanently and significantly reduce TMV or any MC-related contaminants or remove any MEC reasonably possible to detect.

Short-Term Effectiveness - Addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers, the community and the environment during implementation.

Implementability - Addresses the technical and administrative feasibility of implementing a remedial alternative from design through completion.

Cost - Addresses the total cost of each remedial alternative, including consideration of capital costs, annual O&M costs, periodic costs, and present value (USEPA 2000).

State acceptance and community acceptance are modifying criteria that will be evaluated in the Record of Decision following state and public comments on the proposed plan. Modifying criteria consist of the following:

State Acceptance - This criterion addresses state regulatory concerns or issues identified upon review of the FS.

Community Acceptance - This criterion addresses components of an alternative that those in the community identify as presenting a potential issue, concern, or that are simply opposed by the community.

The proposed alternatives were compared based on the NCP and US Army analysis criteria and is summarized below:

Overall Protection of Human Health and the Environment – Potentially unacceptable risk to potential human and ecological receptors from exposure to MEC or MC in soil would remain under Alternative 1. Under Alternative 2, long-term risk to humans and ecological receptors from MEC and MC would be reduced as long as LUCs are enforced and containment measures are maintained. Under Alternative 3, MEC in soil threatening ecological receptors would be removed, permanently reducing long-term risk. For all Alternatives, MC in soil would remain requiring a long term, enforced strategy to conduct site surveys to confirm burrowing owls are not present on the site.

Compliance with ARARs – Alternative 1 would not meet ARARs. Alternatives 2 and 3 would meet ARARs. Waivers would not be required for Alternatives 2 or 3.

Long-Term Effectiveness and Permanence – Under Alternative 1, potentially unacceptable risk to potential human and ecological receptors from potential exposure to MEC and MC in surface soil would remain. Under Alternative 2, risk to human and ecological receptors would be reduced as long as LUCs are enforced, site controls and containment measures are maintained, and semi-annual site surveys are conducted. Under

Alternative 3, residual contamination would pose reduced risk to human industrial/commercial or ecological receptors, and LUCs would reduce the remaining residual risk to human receptors. Long-term reduction of risk to the burrowing owl depends on semi-annual site surveys.

Reduction of TMV – Alternatives 1 and 2 would not reduce the volume of MEC or MC. For Alternative 3, surface clearance would permanently reduce the volume of MEC. Alternatives do not address the reduction of PAHs and lead from soil.

Short-Term Effectiveness – Alternative 3 would pose the greatest risk to site workers during LUC installment and MEC surface clearance. Site workers would need to take the appropriate health and safety precautions during the construction activities for Alternatives 2 and 3.

Implementability – Alternative 1 is not administratively feasible and is therefore difficult to implement. Alternatives 2 and 3 require administrative coordination and enforcement. Alternative 3 involves the use of specialized equipment and specially trained personnel for removal of objects.

Cost – No capital, O&M, or periodic costs are associated with Alternative 1. Alternative 3 is likely to cost 20-25 times as much as Alternative 2. Estimated costs for Alternative 3 are likely to be between $6,000,000 and $7,000,000.

The next step in the restoration process is remedy selection. Based on the FS, Alternative 1 would not meet the RAOs. Alternative 2 would meet RAO 2, RAO 3, RAO 4, and RAO 5 as long as LUCs are maintained and site surveys for the burrowing owl are conducted semi-annually. Alternative 3 would meet all RAOs but it would cost significantly more than Alternative 2. Based on the above analysis, Alternative 2 is selected as the preferred alternative, as it protects human and ecological health, complies with ARARs, and provides the best balance of long term and short term effectiveness, implementability and cost.

As a result of the chosen remedial alternative, MC-contaminated soil at MU732 will not be remediated. This decision was based on the site's remote location, physical and biological properties, and planned future use. With the exception of trespassers, the community as a whole is not in danger of the PAHs and lead on-site. Additionally, there are no plans to develop the property residentially or commercially in the foreseeable future. The physical and biological properties of the site directly affected the effectiveness and implementability of treatment processes. The soil has extremely low moisture content, organic content and vegetation. Due to the depth of groundwater below surface, the necessary water required for in-situ biological treatments is impractical to achieve. If the groundwater at MU732 was at risk of contamination than federal and state ARARs would have mandated the remediation of lead from the soil. MRS SWMU67 at Macdill AFB required the excavation and ex-situ physical/chemical treatment of lead-laden soil due to its proximity to groundwater. The preferred alternative chosen for MRS MU732C at Nellis AFB is similar to Alternative 2 for MU732. MU732C is located a few miles north of MU732 in a rugged, mountainous area. The site investigators did not conduct soil sampling at MU732C due to the terrain and did not identify any ecological receptors. The remedial alternatives for MU732C were based solely on the potential presence of MEC. LUCs were determined suitable to protect human health at MU732C. To protect the burrowing owl from

MC-exposure at MU732, I felt it was necessary to implement a unique remedial process option of relocating the owl away from the site.

CONCLUSION

The MMRP was established to counter the environmental damage caused by the employment of military munitions. Since its establishment in 2001, the DoD has identified 1,674 MRSs at active military installations and has achieved closure of 40 percent of these sites. The program is in full-swing at Nellis AFB where all sites have been identified and initially surveyed. MRS MU732, a small-arms range utilized since the 1940's, has been extensively surveyed and studied. The CSE Phase I, CSE Phase II and RI at MU732 highlighted the presence of MEC and soil concentrations of PAHs and lead hazardous to humans and the burrowing owl, a species regarded as "sensitive" by the Bureau of Land Management – Nevada.

The objective for this project was to develop a FS to demonstrate my understanding of human and environmental risk assessments, remedial technologies and my ability to make decisions based on available scientific information. Upon review of the official reports and the completion of a FS, the preferred remedial action for MU732 is a combination of installment of LUCs and relocation of the burrowing owl to an optimal location in southern Nevada. The next step of the restoration process would be to present my research and proposed remedial alternatives to community stakeholders and state regulators.

Although, my perspective of the MMRP is limited to reports and official DoD documents, I have identified several takeaways and process shortfalls throughout the completion of this project. The bureaucratic nature of government and the US military is evident in this environmental restoration initiative. The MMRP process began at Nellis AFB in 2005 and remedial actions have yet to occur. This can be attributed to the engagement of several DoD agencies, fiscal restraints and extensive process of contracting with the civilian sector. Additionally, I recognized MMRP site reports are virtually inaccessible to civilians and information regarding the MMRP is difficult to find through scientific data repositories. The realm of munitions remediation can benefit through partnerships with DoD and civilian institutions. Finally, my ability to construct a suitable yet feasible remedial alternative was hampered by the lack of hands-on experience I have in this field. Without environmental remediation and project management experience, my knowledge of the capabilities and shortfalls of remedial technologies is bounded by academia.

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APPENDICES

Appendix A: Identification and Initial Screening of Remedial Technologies

Appendix B: Detailed Screening of Technologies and Process Options

Appendix C: Detailed Evaluation of Technologies and Process Options

Appendix A - Identification and Initial Screening of Remedial Technologies

RAO	General Response Action	Remedial Technology	Description	Potentially Applicable
RAO 1	MEC Removal	Manual Removal - Surface Clearance	Manual removal of individual items from the surface by EOD	Yes
		Manual Removal - 1 Foot MEC Removal	Excavation of "hotspots" by heavy equipment. "Hotspots" identified by site survey	Yes
		Manual Removal - Excavate and Sift	Excavation of large quantities of soil and placed in hoppers that shake the soil through screens to filter out large objects.	Yes
	Demolition	Demilitarization	Manual demilitarization of potential residual MEC	Yes
	Disposal	Recycling/Landfill	Scrap/residue excavated and transported to facility for disposal	Yes
RAO 2	Land Use Controls (LUCs)	Fencing	Fencing placed at access areas to physically control access	Yes
		Signage	Signage placed at access areas to control access	Yes
		Administrative Controls	Access restrictions would include documentation. Awareness programs for Air Force personnel	Yes
	In-Situ Physical/Chemical Treatment	Soil Flushing	Water, or water containing an additive to enhance contaminant solubility, is applied to the soil or injected into the ground water to raise the water table into the contaminated soil zone. Contaminants are leached into the ground water, which is then extracted and treated.	Yes
	Ex-Situ Physical/Chemical Treatment (assuming excavation)	1 Foot Soil Excavation - Treated On-Site (Chemical Reduction/Oxidation)	Excavated soils are mixed with oxidizing or reducing agents to stabilize, immobilize, or chemically destroy hazardous contaminants.	Yes
	Excavation and Off-site Disposal	1 Foot Soil Excavation - Treated and Disposed of Off-Site	Soil Excavated, treated and disposed of by Off-Site entity	Yes

RAO 3	LUCs	Fencing	Fencing placed at access areas to physically control access	Yes
		Signage	Signage placed at access areas to control access	Yes
		Adminstrative Controls	Access restrictions would include documentation. Awareness programs for Air Force personnel	Yes
	In-Situ Biological Treatment	Bioventing	Oxygen is delivered to contaminated unsaturated soils by forced air movement to increase oxygen concentrations and stimulate biodegradation.	Yes
		Bioremediation	The activity of naturally occurring microbes is stimulated by circulating water-based solutions through contaminated soils to enhance *in situ* biological degradation of organic contaminants	Yes
		Phyto-remediation	Phytoremediation is a process that uses plants to remove, transfer, stabilize, and destroy contaminants in soil and sediment.	Yes
	In-Situ Physical/Chemical Treatment	Soil Flushing	Water, or water containing an additive to enhance contaminant solubility, is applied to the soil or injected into the ground water to raise the water table into the contaminated soil zone. Contaminants are leached into the ground water, which is then extracted and treated.	Yes
	Ex-Situ Physical/Chemical Treatment (assuming excavation)	1 Foot Soil Excavation - Treated On-Site (Chemical Reduction/Oxidation)	Excavated soils are mixed with oxidizing or reducing agents to stabilize, immobilize, or chemically destroy hazardous contaminants.	Yes
	Excavation and Off-Site Disposal	1 Foot Soil Excavation - Treated and Disposed of Off-Site	Soil Excavated, treated and disposed of by Off-Site entity	Yes
RAO 4	In-Situ Physical/Chemical Treatment	Soil Flushing	Water, or water containing an additive to enhance contaminant solubility, is applied to the soil or injected into the ground water to raise the water table into the contaminated soil zone. Contaminants are leached into the ground water, which is then extracted and treated.	Yes
	Ex-Situ Physical/Chemical Treatment (assuming excavation and relocation of burrowing owl)	1 Foot Soil Excavation - Treated On-Site (Chemical Reduction/Oxidation)	Excavated soils are mixed with oxidizing or reducing agents to stabilize, immobilize, or chemically destroy hazardous contaminants.	Yes

RAO 4	Excavation and Off-Site Disposal (assuming relocation of burrowing owl)	1 Foot Soil Excavation - Treated and Disposed of Off-Site	Soil Excavated, treated and disposed of by Off-Site entity	Yes
	Relocation of Burrowing Owl Supplemented by Site Surveys	Specie Retrieval, Relocation and Site Surveys	Retrieve and relocate burrowing owl. Conducted periodic site surveys to observe presence of burrowing owl.	Yes
RAO 5	In-Situ Biological Treatment	Bioventing	Oxygen is delivered to contaminated unsaturated soils by forced air movement to increase oxygen concentrations and stimulate biodegradation.	Yes
		Bioremediation	The activity of naturally occurring microbes is stimulated by circulating water-based solutions through contaminated soils to enhance *in situ* biological degradation of organic contaminants	Yes
		Phyto-remediation	Phytoremediation is a process that uses plants to remove, transfer, stabilize, and destroy contaminants in soil and sediment.	Yes
	In-Situ Physical/Chemical Treatment	Soil Flushing	Water, or water containing an additive to enhance contaminant solubility, is applied to the soil or injected into the ground water to raise the water table into the contaminated soil zone. Contaminants are leached into the ground water, which is then extracted and treated.	Yes
	Ex-Situ Physical/Chemical Treatment (assuming excavation and relocation of burrowing owl)	1 Foot Soil Excavation - Treated On-Site (Chemical Reduction/Oxidation)	Excavated soils are mixed with oxidizing or reducing agents to stabilize, immobilize, or chemically destroy hazardous contaminants.	Yes
	Excavation and Off-Site Disposal (assuming relocation of burrowing owl)	1 Foot Soil Excavation - Treated and Disposed of Off-Site	Soil Excavated, treated and disposed of by Off-Site entity	Yes
	Relocation of Burrowing Owl Supplemented by Site Surveys	Specie Retrieval, Relocation and Site Surveys	Retrieve and relocate burrowing owl. Conducted periodic site surveys to observe presence of burrowing owl.	Yes
Other	No Action	None	No remedial action would be taken to address potential MEC hazards	Yes

Appendix B - Detailed Screening of Technologies and Process Options

General Response Action	Remedial Technology	Description	Effectiveness	Implementability	Cost	Screening Comments	RAO 1	RAO 2	ROA 3	RAO 4	RAO 5	ROA 6
MEC Removal	Manual Removal - Surface Clearance	Manual removal of individual items from the surface by EOD	Medium: Very effective but does not address subsurface MEC	Medium - High: Requires qualified EOD technicians	Low - Med	Retained	**X**					
	Manual Removal - 1 Foot MEC Removal	Excavation of "hotspots" by heavy equipment. "Hotspots" identified by site survey	Medium - High: Very effective but uncertainty remains regarding the presence of subsurface MEC	Medium: Requires one of the highest degrees of direct MEC exposure for workers. Intrusive actives add increased risk to workers.	High	REJECTED: Small cost savings compared to insignificant decrease in risks over other surface clearance alternatives.	**X**					
	Manual Removal - Excavate and Sift	Excavation of large quantities of soil and place in hoppers that shake the soil through screens to filter out large objects.	High: Results in a high degree of confidence that MEC is effectively removed.	Low: Requires multiple pieces of heavy, specialized, hardened and armored equipment and skilled operators.	High	REJECTED: High degree of implementability and high cost considering size of site.	**X**					
Demolition	Demilitarization	Manual demilitarization of potential residual MEC	Medium: MEC may be impacted in soil and EOD may not be able to locate	High: Personnel available and no special equipment needed.	Low	Retained	**X**					
Disposal	Recycling/Landfill	Scrap/residue excavated and transported to facility for disposal	High: Removes debris from site and eliminates potential human risks.	Medium: All hazardous materials must be removed prior to release to commercial industry	Med - Low	REJECTED: Small cost savings compared to demilitarization by AF Personnel	**X**					

Land Use Controls (LUCs)	Fencing	Fencing placed at access areas to physically control access	Medium: Is not effective against trespassers	Medium: Fencing would be difficult to implement because of the large area and terrain	Med	Retained	**X**	**X**	**X**			
	Signage	Signage placed at access areas to control access	Medium: Moderately effective in reducing risk associated with potential MEC	High: Easily Implemented	Low	Retained	**X**	**X**	**X**			
	Administrative Controls	Access restrictions would include documentation. Awareness programs for Air Force personnel	Low - Medium: Provides minimal measures to reduce exposure risk for humans	High: Easily Implemented	Low	Retained	**X**	**X**	**X**			
In-Situ Physical/Chemical Treatment	Soil Flushing	Water, or water containing an additive to enhance contaminant solubility, is applied to the soil or injected into the ground water to raise the water table into the contaminated soil zone. Contaminants are leached into the ground water, which is then extracted and treated.	High: Mobilizes metals/allows for capture	Low: Significant amount of groundwater required	High	REJECTED: Not cost effective than alternative technologies		**X**		**X**		
Ex-Situ Physical/Chemical Treatment (assuming excavation)	1 Foot Soil Excavation - Treated On-Site (Chemical Reduction/Oxidation)	Excavated soils are mixed with oxidizing or reducing agents to stabilize, immobilize, or chemically destroy hazardous contaminants.	Medium:	Low: Requires multiple pieces of heavy, specialized, hardened and armored equipment and skilled operators.	High	REJECTED: High degree of implementability and high cost considering size of site.		**X**	**X**	**X**	**X**	
Excavation and Off-site Disposal	1 Foot Soil Excavation - Treated and Disposed of Off-Site	Soil Excavated, treated and disposed of by Off-Site entity	High: Properly treated and disposed of	Low: Requires multiple pieces of heavy, specialized, hardened and armored equipment and skilled operators.	High	REJECTED: High degree of implementability and high cost considering size of site.		**X**	**X**	**X**	**X**	

In-Situ Biological Treatment	Bioventing	Oxygen is delivered to contaminated unsaturated soils by forced air movement to increase oxygen concentrations and stimulate biodegradation.	High: Effective at removing petroleum products	Low: Soil moisture content of site extremely low	Low	REJECTED: Low soil moisture content			**X**		**X**	
	Bioremediation	The activity of naturally occurring microbes is stimulated by circulating water-based solutions through contaminated soils to enhance *in situ* biological degradation of organic contaminants	High: Effective at removing petroleum products	Low: Significant amount of groundwater required	Medium	REJECTED: Requires significant amount of groundwater. Small cost savings having to drill for deep groundwater.			**X**		**X**	
	Phyto-remediation	Phytoremediation is a process that uses plants to remove, transfer, stabilize, and destroy contaminants in soil and sediment.	Medium: Effective at removing petroleum products/can be rather slow	Medium: Large site/lack of vegetation in region	Low	REJECTED: Lack of vegetation/ suitability for vegetation			**X**		**X**	
Relocation of Burrowing Owl Supplemented by Site Surveys	Specie Retrieval, Relocation and Site Surveys	Retrieve and relocate burrowing owl. Conducted periodic site surveys to observe presence of burrowing owl.	Medium: Upon relocation, burrowing owl is no longer under the threat of PAH/lead exposure.	High: Burrows can be located and owls can be relocated by experts	Low	Retained				**X**	**X**	
No Action	None	No remedial action would be taken to address potential MEC hazards	Low: No MEC removed	High	Low	Retained: Required for comparison with other alternatives						

Appendix C - Detailed Evaluation of Technologies and Process Options

EVALUATION CRITERIA	Alternative 1- No Action	Alternative 2 – LUCs/Relocation of Burrowing Owl	Alternative 3 - MEC Removal/LUCs/Relocation of Burrowing Owl
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT			
Human Health Protection	Would not reduce risk to human health.	Would be protective of human health if institutional/engineering controls are properly administered to limit MEC/receptor interaction	Would be protective of human health if institutional/engineering controls are properly administered to limit MEC/receptor interaction. Would reduce risk to receptors for MEC located on surface.
Environmental Protection	Would not reduce risk to burrowing owl health.	Would be protective of burrowing owl health. Not expected to have a negative impact on the ecosystem.	Would be protective of Burrowing Owl health. Not expected to have a negative impact on the ecosystem.
COMPLIANCE WITH ARARs			
Compliance with ARARs	Not applicable.	Would meet ARARs.	Would meet ARARs.
Appropriateness of Waivers	Not applicable.	None should be required.	None should be required.
LONG-TERM EFFECTIVENESS			
Magnitude of Residual Risk	Risks to potential future receptors would remain indefinitely	Risks to potential future receptors would remain indefinitely. Risk to human health would be limited due to LUCs. Risk remains for burrowing owl that remain on site between semi-annual relocating.	Risks to potential future receptors would be reduced in cleared areas of the MRS. Risk would be further limited due to LUCs. Risk remains for Burrowing Owls that remain on site between semi-annual relocating.
Adequacy and Reliability of Controls	Not applicable.	Institutional controls would educate, regulate, and ensure adequate warning to those allowed access to the MRS. Engineering controls would ensure limited access to the MRS. Does not reduce risk for Burrowing Owl.	Institutional controls would educate, regulate, and ensure adequate warning to those allowed access to the MRS. Engineering controls would ensure limited access to the MRS.
REDUCTION OF TMV			
Treatment Process Used	None.	None.	None.

Reduction of TMV	None.	None.	Total volume of MEC would be reduced.
SHORT-TERM EFFECTIVENESS			
Time Required to Achieve RAOs	Would not achieve RAOs.	RAOs 2,3,4,5 would be achieved upon implementation of LUCs. Would not achieve RAO 1	RAOs would be achieved upon completion of surface MEC removal, implementation of LUCs and relocation of Burrowing Owl.
Protection of Community During Remedial Action	Not applicable.	The community would not be put at risk during the remedial action.	The community would not be put at risk during remedial action.
Protection of Workers During Remedial Action	Not applicable.	Construction support and oversight would be provided during the installation of LUCs.	Workers would follow proper safety precautions during site clearance, MEC removal and disposal. Aviary experts would be provided support and oversight while on site.
IMPLEMENTABILITY			
Ability to Construct and Operate	Not applicable.	Easy to implement. Aviary experts are available within State Fish and Game to relocate Burrowing Owl but moderately difficult to implement.	Detection and disposal technologies are readily available and would be moderately easy to implement. Aviary experts are available within State Fish and Game to relocate Burrowing Owl but moderately difficult to implement.
Technical Feasibility	Not applicable.	Technology is reliable and readily available.	Technology is reliable and readily available.
Administrative Feasibility	Not applicable.	Moderately easy to implement LUCs.	Moderately easy to implement LUCs.
COST			
Project Duration (years)	0	30	30
Capital Cost	$0	$126,000	$1,626,000
Annual O&M Cost	$0	$9,600	$7,400
Total Cost of Alternative	$0	$414,000	$1,848,000