Technical/Regulatory Guidelines

Characterization and Remediation of Soils at Closed Small Arms Firing Ranges

January 2003

Prepared by
Interstate Technology and Regulatory Council
Small Arms Firing Range Team

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ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

Small arms firing ranges (SAFRs) include government, commercial, and recreational rifle, pistol, trap, skeet, and sporting clay ranges. Small arms firing ranges are those ranges accepting 50 caliber or smaller ammunition. This definition is meant to include shotgun ammunition used on trap- and skeet-type ranges. SAFRs may contain lead, antimony, copper, zinc, arsenic, and polycyclic aromatic hydrocarbons (PAHs) from nonexploding (nonenergetic) bullets and fragments, bullet jackets, and related sporting material (e.g., clay targets); however, lead is the primary risk driver and is thereby the focus of this guidance.

Lead has documented impacts on human health, particularly for children. There are many mechanisms for exposure to lead, including drinking lead-contaminated groundwater, ingesting lead-contaminated soil or sediment, or inhaling airborne particles of lead. Lead dissolution and migration to groundwater or through aerially (windblown) or hydraulically (erosion and deposition) dispersed particles can cause exposure and result in elevated levels of lead in the blood of humans and wildlife and may ultimately impact beneficial future land use.

The U.S. Department of Defense (DoD) oversees more than 3,000 active SAFRs as well as the closure, or pending closure, of 200 more. In all, DoD expends more than 2 million pounds of lead annually. In addition to DoD facilities, there are an estimated 9,000 nonmilitary outdoor ranges in the United States (USEPA, January 2001). USEPA also estimates that 4% of the 80,000 tons of lead produced in the United States during the late 1990s was made into bullets and shot.

This guidance is designed to display a logical and easy-to-follow decision diagram for determining how best to remediate lead and lead-contaminated soils at closed small arms firing ranges. A decision diagram is included to assist the practitioner in formulating a proper strategy for removing the threat that metal, particularly lead, presents at small arms firing ranges. This decision diagram and accompanying documentation is valuable for planning, evaluating, and approving lead soil remediation systems. It defines site parameters and appropriate ranges of criteria necessary for characterizing, testing, designing, and monitoring lead soil remediation technologies. Contaminants, associated chemicals of concern, and contaminant distribution may differ among small arms firing ranges; however, many characteristics of a site, necessary to determine the efficacy of lead remediation technologies, are similar. Once a site has been characterized and the postremediation land use of the site established, engineered approaches can be designed, tested, and deployed. The decision diagram defines the primary decision points and provides characteristics used to evaluate various lead soil remediation strategies. The flow diagram references the sections where each element is more thoroughly discussed in the body of the document. When viewing the flow diagram electronically, simply click on the box in the flow diagram to proceed directly to that section for additional information. This approach is useful to state and federal regulators, environmental consultants, responsible parties/owners, and community stakeholders.

Site owners and operators have only recently become familiar with the environmental consequences of their practice. Their industry has since developed Best Management Practices (BMPs) for environmental management and maintenance of their range and, consequently, operators are incorporating these into their operating procedures. Federal agencies, specifically DoD, and commercial sporting range operators are proactively developing a greater understanding of lead management and remediation. There are a number of remediation technologies as well as sampling and analysis techniques that, if appropriately applied, can adequately characterize and remediate lead contamination at any SAFR.

Because of the increased scrutiny being paid to SAFRs, the U.S. Department of Navy, USEPA Region 2, and the state of Florida have developed BMP documents to provide guidance on the operation of active SAFRs. These documents closely follow the guidance provided by the National Shooting Sports Foundation (www.rangeinfo.org).

While researching and compiling information for this guidance, the team identified a number of regulatory and technical issues encountered while remediating a SAFR. Through this guidance, the team seeks to clarify these issues and make recommendations, which in the team's view enhance the use of the techniques discussed in the guidance. Following are some of the more significant issues identified by the team. See Section 6.0 of this guidance for further discussion:

- At some ranges, it may be possible and desirable to reuse the soil from the backstop of a range that is being closed to construct a new berm or rebuild an existing berm located in another area of the same property or facility. It is USEPA's position that ranges that reclaim and recycle lead bullets or lead shot may place the soil that is generated during the reclamation process back onto an active range on the same property or facility or a property adjacent to and under the same ownership as the property where the soils originated without testing the soil for hazardous waste characteristics.

- It has been suggested that range soil from a former backstop may also be reused, following lead reclamation, for constructing or rebuilding a backstop at a location that is not on the range property. The same environmental benefits from berm reuse as described later in this document could be realized, but extra oversight may be needed. Since individual states may not permit this action, or may impose additional requirements for transportation, documentation, and approvals, state regulations and regulatory agencies should be consulted prior to transporting range soils to a property that is not the same as or adjacent to and under the same ownership as the property where the soils originated.

- While many current analytical methods rely on using only soil that has been passed uncrushed through a 30-mesh sieve as the source for analytical tests, some controversy exists in the field as to the best method(s). Other sample preparation protocols have been proposed and approved by governing regulatory bodies. Differences in sample preparation protocols include the designation of the size of sieve or whether to use a sieve at all and on the degree of disaggregation prior to sieving. Therefore, to recommend a specific sample preparation method may be misleading. No matter which method is selected, however, it should result in a sample that is representative of the site and its environment and is agreeable to the regulatory community and the other parties involved in the evaluation.

Other recommendations on relevant issues can be found throughout this document. Please refer to Section 6.0 for a comprehensive listing of all issues contained in this document.

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1.0 INTRODUCTION

Small arms firing ranges (SAFRs) include government, commercial, and recreational rifle, pistol, trap, skeet, and sporting clay ranges. Small arms firing ranges are those ranges accepting 50 caliber or smaller nonexploding ammunition. This definition is meant to include shotgun ammunition used on trap- and skeet-type ranges. Small arms firing ranges may contain lead, antimony, copper, zinc, arsenic, and polycyclic aromatic hydrocarbons (PAHs) that may leach from bullets and fragments, bullet jackets, and related sporting material (e.g., clay targets), thereby contaminating soils and possibly surface and groundwater (NFESC, 1997). Table 1-1 lists components used to manufacture ammunition and clay targets.

Constituent	Comment
Lead	Primary constituent of a projectile
Lead Styphnate/Lead Azide	Primary constituent
Antimony	Increases hardness
Arsenic	Present in lead. A small amount is necessary in the production of small shot since it increases the surface tension of dropped lead, thereby improving lead shot roundness.
Copper bullet core alloy	Increases hardness
Tin	Increases hardness
Copper	Jacket alloy metal
Zinc	Jacket alloy metal
Iron	Iron tips on penetrator rounds
PAHs (Polycyclic Aromatic Hydrocarbons)	Concentration of PAHs in clay targets varies from one manufacturer to the next but may be as high as 1000mg/kg. Existing studies show that PAHs are bound within the limestone matrix of the target and are, therefore, not bioavailable.

Table 1-1. Contaminants Potentially Found at Small Arms Firing Ranges
(Information obtained from Tables 2-1 & 2-2 in NFESC, 1997)

Lead accounts for more than 85% of the weight of the projectile and constitutes the greatest environmental concern. If the projectile fragments upon impact, it creates lead dust, which can be carried off site by either wind or water erosion. The heat of firing bullet projectiles can also atomize lead in a sort of lead vapor, which can precipitate or condense on soil particles at the firing line.

Lead has documented impacts on human health, particularly for children. There are many mechanisms for exposure to lead, including drinking lead-contaminated groundwater, ingesting lead-contaminated soil or sediment, or inhaling airborne particles of lead. Lead dissolution and migration to groundwater or through aerially (windblown) or hydraulically (erosion and deposition) dispersed particles can cause exposure to lead and result in elevated levels of lead in the blood of humans and wildlife and may ultimately impact future land use. Remediation of soils at small arms firing ranges presents unique challenges because lead and associated co-contaminants (see Table 1-1) exist as both discrete particles and as sorbed compounds dispersed within the soil matrix. The form and distribution of particulate lead varies based on range use, size and impact velocity of the round, soil characteristics, and past range maintenance practices.

For rifle and pistol ranges, most training is done with fixed or stationary targets at known distances, resulting in the formation of "bullet pockets" on the face of the berm. The high-impact energy of these high-speed rounds with the rounds accumulated in the bullet pockets results in significant fragmentation and ricochet. To mitigate ricochet, standard range maintenance practices include "refacing" and/or turning the berm soil over to bury the projectiles below the impact depths of incoming rounds. As a result, particulate lead can be found at depths below traditional impact depths; and the particles range from whole, relatively intact projectiles to microscopic metal particles. This heavy accumulation of lead in a relatively small soil volume coupled with the fine lead present results in range soils high in total lead, which can fail standard leachability tests such as the RCRA Toxicity Characteristic Leaching Procedure (TCLP) and the Synthetic Precipitation Leaching Procedure (SPLP).

Shotgun ranges (skeet, trap, and sporting clays), on the other hand, typically involve widely dispersed lead particles that fall to the ground with little impact energy. Remediation of these ranges involves large soil volumes with relatively low particulate lead concentrations. However, based on the age of the range and soil chemistry, lead shot can corrode into a wide range of various particle sizes. Since the pellets have little impact energy, fragmentation is not an issue. However, Craig, et al. (2002) reports evidence of fragmentation associated with short-range, low-angle shotgun shots.

The disk-like, flying targets used at shotgun ranges contain PAHs. However, Baer (1995) found that the targets did not exhibit the characteristics of toxicity as determined by an USEPA toxicity test even though they contained high levels of PAHs. The state of Connecticut accepted these findings and treated the targets at the site as solid rather than hazardous wastes.

1.1 Problem Statement

The U.S. Department of Defense (DoD) oversees more than 3,000 active SAFRs as well as the closure, or pending closure, of 200 more. In all, DoD expends more than 2 million pounds of lead annually. In addition to DoD facilities, there are an estimated 9,000 nonmilitary outdoor ranges in the United States (USEPA, January 2001). USEPA also estimates that 4% of the 80,000 tons of lead produced in the United States in the late 1990s was made into bullets and shot. Several existing environmental regulations can apply to shooting ranges. Developing and implementing an Environmental Stewardship Plan or Best Management Practices as outlined by the firearms industry (www.rangeinfo.org), USEPA, or the Florida Department of Environmental Protection is an important range management activity to prevent environmental and/or regulatory problems. Federal agencies, specifically DoD, and commercial sporting range operators are proactively developing a greater understanding of lead management and remediation. There are a number of remediation technologies as well as sampling and analysis techniques that, if appropriately applied, can adequately characterize and remediate lead contamination at any SAFR.

1.2 Purpose

This guidance is designed to display a logical and easy-to-follow decision diagram for determining the best remediation alternative for lead at closed small arms firing ranges (SAFRs). The decision diagram, Figure 1-1, contains the general decision points when considering soils remediation at closed SAFRs. How to best manage lead at active and inactive small arms firing ranges is the subject of a follow-on ITRC project scheduled for completion in 2003.

The decision diagram (Figure 1-1) is included to assist the practitioner while formulating a proper strategy for removing the threat that metal, particularly lead, presents at small arms firing ranges. This decision diagram and accompanying documentation is valuable for planning, evaluating, and approving lead soil remediation systems. It defines site parameters and appropriate ranges of criteria necessary for characterizing, testing, designing, and monitoring lead soil remediation technologies. Contaminants, associated chemicals of concern (CoCs), and contaminant distribution may differ among small arms firing ranges; however, many characteristics of a site necessary to determine the efficacy of lead remediation technologies are similar. Once a site has been characterized and the postremediation land use of the site established, engineered approaches can be designed, tested, and deployed. The decision diagram defines the primary decision points and provides characteristics used to evaluate various lead soil remediation strategies. The flow diagram references sections where each element is more thoroughly discussed in the body of the document. When viewing the flow diagram electronically, simply click on the box in the flow diagram to proceed directly to that section for additional information. This approach is useful to state and federal regulators, environmental consultants, responsible parties/owners, and community stakeholders.

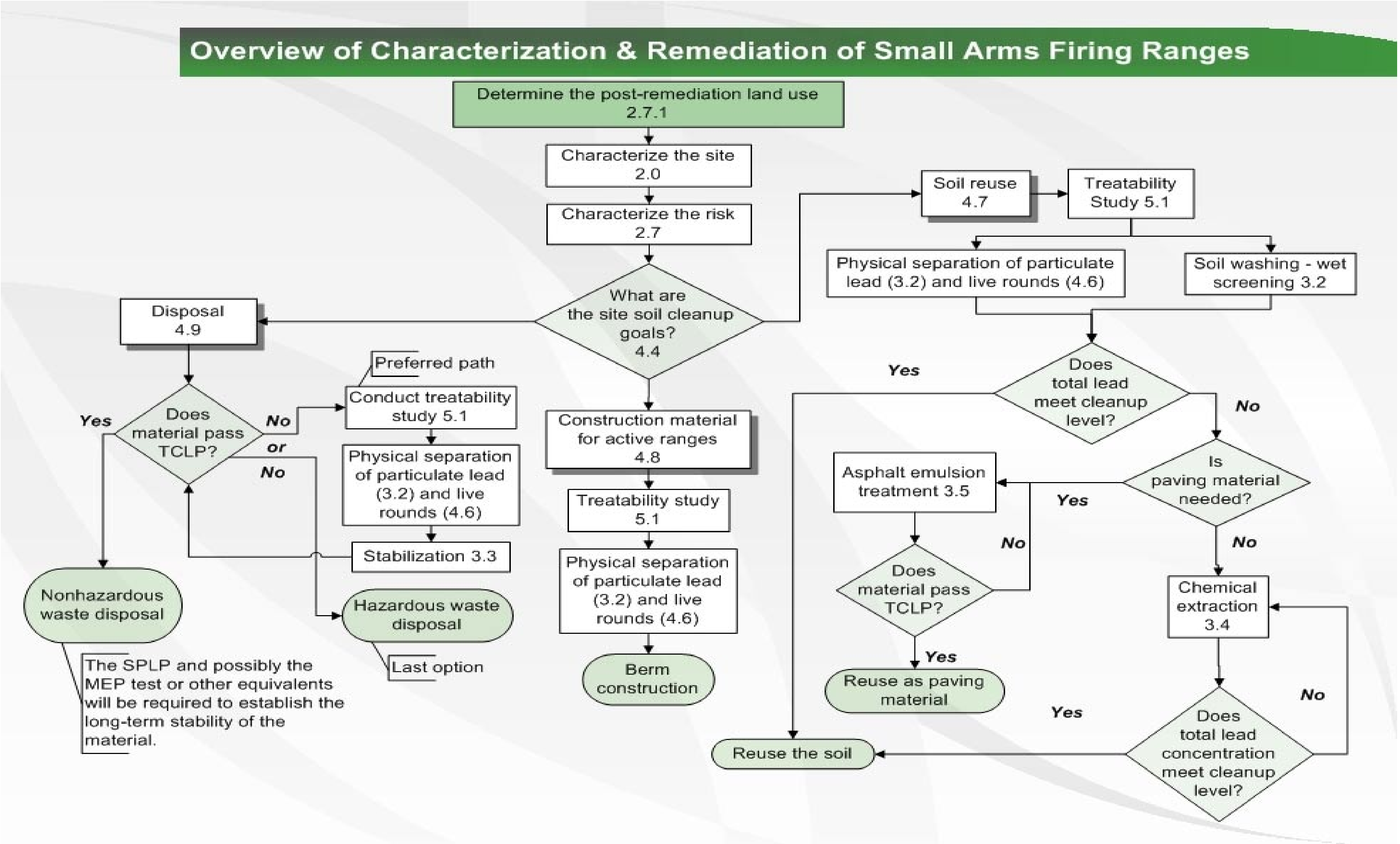


Figure 1-1. Decision Tree: Characterization and Remediation of Closed Small Arms Firing Range Soils

2.0 SITE CHARACTERIZATION

Site characterization assesses the extent and nature of the contaminants of concern as an initial step in the cleanup of a small arms firing range. The general approach for a small arms firing range site characterization is identical to that used in the assessment of any site where metals or other regulated hazardous chemical constituents have been released to the environment. Site characterization should answer the following questions:

- What are the contaminants of concern (CoCs) in addition to lead at the subject ranges?
- What is the vertical and horizontal extent of the lead and other CoCs in the environment?
- What are the concentrations of these contaminants across the affected area?
- What environmental media are impacted (i.e., soil, surface water, groundwater, air, sediment)?
- Are the impacted areas limited to locations where bullets and shot were initially deposited or has there been vertical/horizontal migration of the contaminants of concern?
- If migration has occurred, what are the likely routes of migration?
- What are existing or potential human or environmental exposure pathways?
- Is there a potential UXO present?

Before any actual sampling is conducted at a range to answer these questions, one should gather available records and accounts of the range history, use, and layout. These aspects of the site characterization are discussed below.

2.1 Range History and Records

To determine where lead and any other contaminants associated with the deposition of bullets and/or lead shot pellets are present in the environment, information should be gathered regarding the location of all current ranges that are subject to cleanup, as well as any abandoned ranges. This information can be obtained from written records, plans, photographs, etc. kept by the facility and/or through interviews with persons familiar with past operations. Current and historical aerial photographs are often excellent sources of information on range layout.

Information should also be gathered on the period of time during which each range was in use, the estimated amount of shooting done during that time, the type of ammunition used, and the reclaiming and recycling history of the site. For trap and skeet ranges, the amount of lead shot pellets deposited at a range may be estimated based on the number of targets used annually by the facility. Additionally, information should be obtained regarding any removal and relocation of soils from ranges to other locations at the range or off site. Areas that received soil that was likely contaminated with lead should be included in the site characterization.

Available surveys and property maps of the facility and ranges should be obtained. An examination of property boundaries with respect to range layout and areas where ammunition is deposited should be performed to determine whether any off-property impacts exist.

2.2 Range Design Considerations

The design and use of a shooting range will have a direct impact on where the lead will be deposited. Researching the range design(s) and past use(s) will help you identify where the lead will be found and help focus the remediation efforts. There are four different types of outdoor ranges: shotgun ranges, static ranges, dynamic ranges, and interactive ranges. Confusing the issue is the possibility that over the years a range may actually consist of several different ranges—one overlaid on top of another.

Users of a shotgun range shoot at airborne discs using ammunition that typically consists of between 1 ounce and 1-1/8 ounces of lead pellets. The pellets are very small in diameter (from .08 to .095 inches), which means the ammunition contains a large number of pellets (from 350 to 650 pellets per cartridge). These pellets have a maximum distance of between 660 feet and 770 feet from the shooter. Shotgun ranges are primarily used for recreation; however, the Army Air Corps used shotgun ranges for initial training in the skills needed to shoot down enemy airplanes. These ranges are not always over dry land. The impact areas for some of these ranges may be over wetlands or even open water. The National Association of Shooting Ranges, a division of the National Sports Shooting Foundation (NSSF), has published *Environmental Aspects of Construction and Management of Outdoor Shooting Ranges*, which describes the standard designs of trap (Figure 4-2), skeet (Figure 4-3), and conceptual design of sporting clays (Figure 4-4) www.rangeinfo.org.

Static ranges, dynamic ranges, and interactive ranges are used with rifles and handguns but can also include shotguns using large projectiles (known as “buckshot” and “slugs”). The static range is one where a stationary shooter fires at a known target located at a known distance. Most military basic training as well as recreational shooting is static. The dynamic range is one where there is movement on the part of the shooter firing at a known target. Finally, the interactive range is where there is movement on the part of the shooter, who is firing at targets that may also be moving, are randomly located, or are a surprise to the shooter. Interactive ranges are used primarily in law enforcement and military training but can also be part of advanced self-defense training.

There are different site characterization and environmental management implications for each of these four types of ranges. The shotgun range will have a widely scattered deposition of very small pellets (of a consistent size and shape) within an area no more than 770 feet from the shooting position, with the majority of the lead being deposited at a distance between 375 feet and 600 feet from the shooter. The shape and size of the area of shot deposition, or “shotfall zone,” depends on the kind of recreational shooting done at the range (i.e., trap, skeet, or sporting clays) and the number of fields (single or multiple) (NSSF, 1997, pp. 4.1–4.7). The pellets will typically be found within inches of the surface, unless tilling or digging has physically disturbed the area.

The static range has lead very concentrated in a very small area directly behind each target. The lead may be found up to two feet into a primary impact berm. Lead from static ranges can also migrate due to erosion from the berm material, through surface water runon and runoff. The targets are typically set between 5 feet and 8 feet apart in a straight line parallel to the firing line. Dynamic ranges also have small and identifiable lead deposits behind each target, but the targets are more randomly and widely dispersed. This layout results in specific areas of lead deposition in moderate concentration dispersed over a larger area.

2.3 Rifle/Handgun Firing Range Layouts

To effectively characterize the soil in each area for various range layouts, it is necessary to understand how the depth and aerial extent of particulate lead distribution varies with each type of range layout. The traditional layout of training areas can involve a central impact area for large munitions, ringed by SAFRs on the perimeter for firing toward the center. As a result, the safety fans and projectile flight paths can overlap, resulting in unexploded ordnance (UXO) unexpectedly turning up in SAFR soils and small arms projectiles in impact area soil. In addition to the safety issues associated with UXO (www.itrcweb.org, see the ITRC UXO guidance document), there are also contaminant issues with unburned propellants and explosives, which are present as microscopic discrete particles dispersed over a wide area, not unlike the dispersion of lead shot at a skeet range.

A rifle/handgun firing range has the following major areas (see Figure 2-1):

- Primary Impact Berm
- Range Floor
- Lateral or Side Berms
- Safety Fan, or Fallout Area

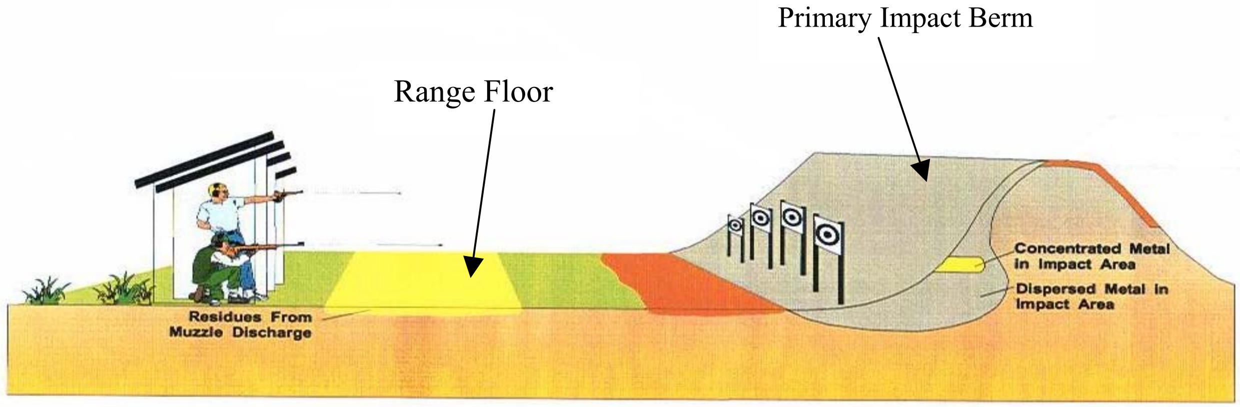


Figure 2-1. Cross Section of a Typical Static Rifle and Handgun Range
(Modified from Figure 1.1 in AFCEE, 2000)

2.3.1 Primary Impact Berm

The primary impact berm faces the shooter and takes the bullet head on. As such, the full force of impact is absorbed by the berm. Two mechanisms at work to scrub energy and stop the bullet are displacement of soil particles and fragmentation of the lead projectile. In sandier soils, displacement of the soil particles allows the bullet to penetrate a foot or more into the berm, with soil resistance increasing with depth. Eventually, all of the energy is scrubbed, and the bullet comes to rest basically intact and buried within the soil matrix. Hard-packed berm soil, surfacial lead buildup, or the presence of rocks causes the lead to fragment upon impact. Fragmentation also scrubs energy but creates undesirable byproducts—the generation of lead dust and fragments that increase the aerial extent of remedial efforts. Ricochet, which can present serious threats to shooters, bystanders, and neighboring properties, further expands the area that needs to be addressed by cleanup efforts.

2.3.2 Range Floor

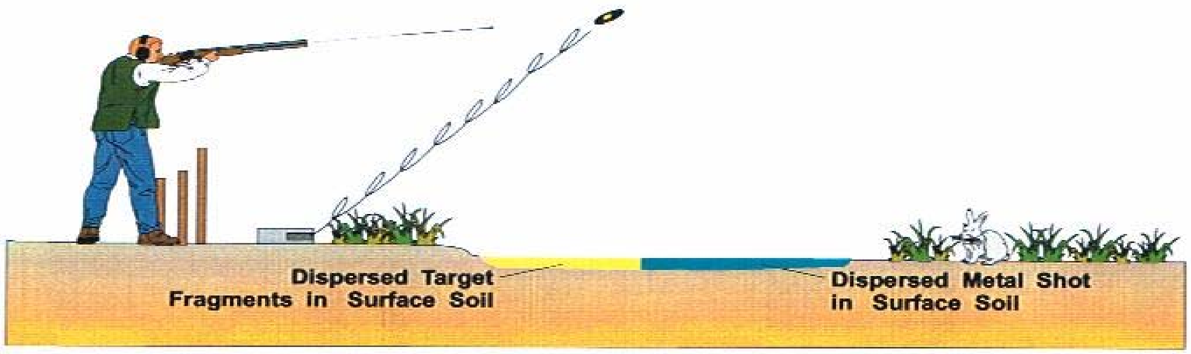
The range floor is defined as the ground between the firing line and the primary impact berm, with a width equal to the width of the range lanes. This surface rarely receives direct fire and as such the particulates are shallow as compared to the primary impact berm. Rounds that impact the range floor are typically a flat trajectory that fell short of the berm or those that result from ricochet. The resulting projectiles/fragments are typically found lying on the surface or embedded in the root mass of the range floor vegetation, usually within the top 6 inches of soil. Live rounds are also found on a regular basis in this area, as there are misfires that were ejected and lost or dropped rounds that were not picked up. Empty brass is also common in this area, and casings also represent a potential source of lead because the initiators, or primers, use shock-sensitive lead compounds with residuals left in the casing after firing. The muzzle blast deposits these same lead compounds, as well as lead dust resulting from the rifling on the barrel of the weapon cutting into the projectile as it leaves the barrel. Typical depths of penetration on the range floor are 1 foot or less.

2.3.3 Lateral, or Side, Berms

Lateral berms separate contiguous ranges within a complex or provide containment at the perimeter. Like the range floor, they rarely receive direct fire and typically collect ricochets and the occasional stray round, which results from cross fire across lanes. The typical penetration depth is 1 foot. These berms may also be used on shotgun ranges.

2.3.4 Safety Fan/Fallout Area

On most range types, the rounds/fragments found in the safety fan/fallout area are almost exclusively the result of ricochet. Unless earthmoving is performed, the fragments lie on the surface. The exception to this rule is trap and skeet ranges, where distance is used to collect projectiles and the fallout area is the part of the range receiving most impact. If sampling is required, it should be conducted on the range floor, where most times fragments can be vacuumed up without any excavation.



Schematic Cross Sectional View

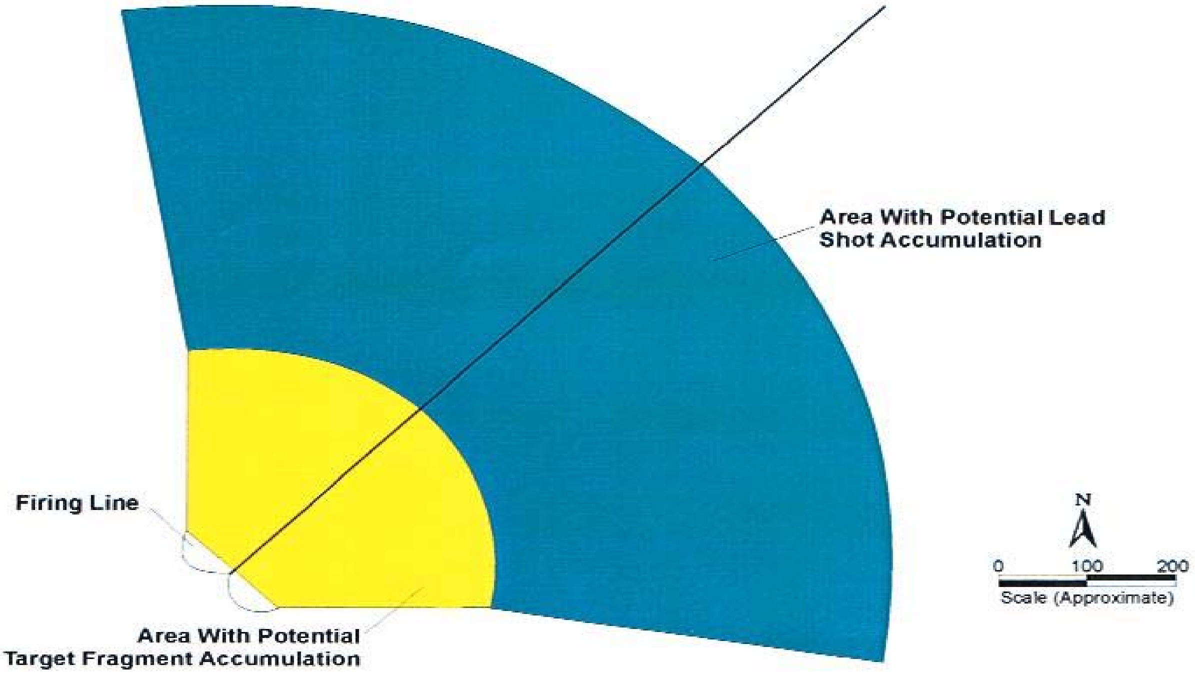


Figure 2-2. Cross Section and Plan View of Shotgun Range Layout and General Shotfall Zone (Modified from Figure 2-1 in AFCEE, 2000)

2.4 Shotgun Range Layouts

The primary characteristic of all shotgun ranges from an environmental perspective is the wide distribution of shot. This results in a relatively large area in which there might be a concern. The full extent of the total shotfall zone must be known before effective lead management practices can be implemented. Because clay targets are thrown at different angles for each of the different shotgun shooting venues, the type of venue will determine the dispersion of the spent shot.

2.4.1 Trap Range Layout (NSF, 1997)

The positions of the shooters and the angles at which trap targets are thrown result in a funnel-shaped shotfall zone. Depending on the load, the angle at which the shot was fired, and wind direction, typical lead trap loads can reach nearly 770 feet from the shooter. The theoretical shotfall zone and the area of maximum shotfall are illustrated in Figure 2-3. Note the overlap of the shotfall zone from adjacent fields, resulting in areas with increased amounts of lead**.**

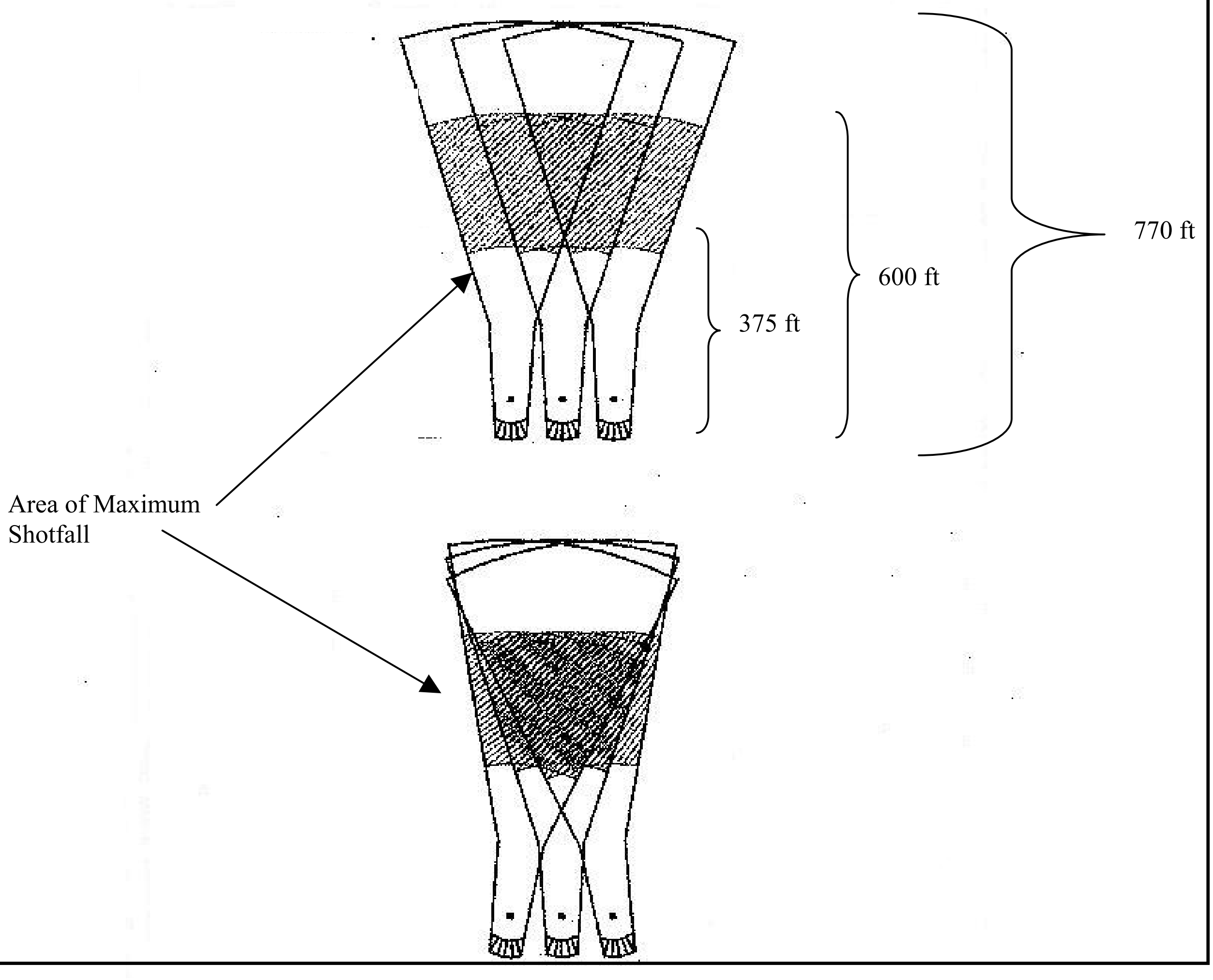


Figure 2-3. Schematic Drawing of Trap Range Layout (Modified from NSSF, 1997)

2.4.2 Skeet Range Layout

The positions of the shooters and the angles at which skeet targets are thrown results in a "fan-shaped shotfall zone. Depending on the load, the angle at which the shot was fired, and the wind direction, typical lead skeet loads can reach about 680 feet from the shooter (see Figure 2-4).

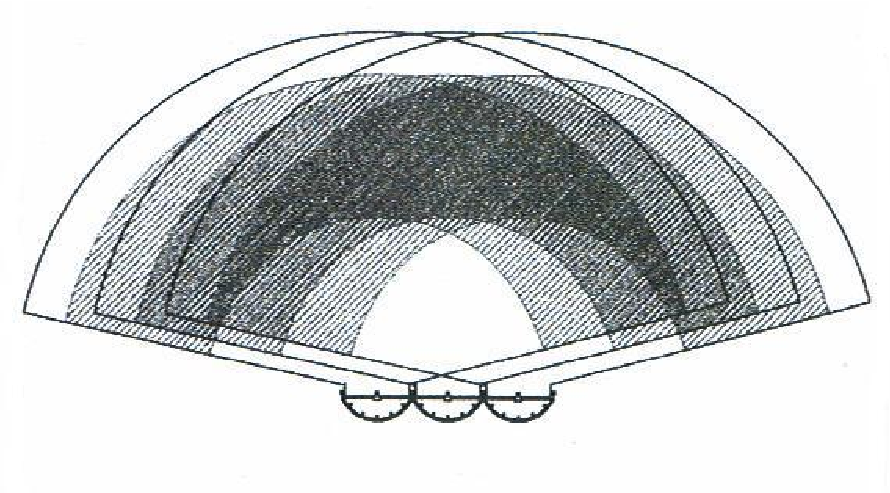


Figure 2-4. Schematic Drawing of Skeet Range Layout
(NSSF, 1997)

2.4.3 Sporting Clays Range Layout (NSSF, 1997)

The defining feature of sporting clays courses is the complete flexibility in target angles and shooting directions. Because there is no "standard" layout for sporting clays courses, it is impossible to illustrate a "standard" shotfall zone or area of maximum shotfall. When investigating closed facilities, efforts need to focus on identifying the locations of shooting stations and the target launcher in order to estimate where the shooter engaged the target. Unlike most shotgun ranges, stations at some sporting clays may involve low-angle, short-distance shotgun shots. Craig et al. (2002) has reported at the Winter Workshop and Meeting of the Virginia Chapter of the Wildlife Society that fragmentation may be more evident in these types of situations.

2.5 Fate and Transport Considerations

Sources of lead on military and civilian small arms firing ranges include spent bullets and residues of lead compounds used in small-caliber bullet primer and igniter formulations. Small-caliber military bullets (5.56mm and 7.62mm) have spent bullets composed of antimony-hardened lead in a copper jacket. The copper in a jacketed bullet remains in close proximity to the lead core. When the metals are exposed to moisture, an electrical connection between two dissimilar metals is established, and the electron flow between them may result in galvanic corrosion.

Bullet masses range from 32 to 86 grams per bullet, of which 96.4% by weight is lead (MIDAS, 2002). Common military primer formulations (FA-956 and FA-70), igniters, and propellants include organolead compounds (lead thiocyanate, lead styphnate, lead stearate, lead salicylate) at approximately 0.1 to 0.2 grams per bullet (MIDAS, 2002). Lead carbonate also is added to inhibit corrosion of gun barrels. The primary sources of lead at training ranges are spent bullet projectiles and shot pellets. However, given the multiple uses of military ranges, residues from unignited propellant and explosives from artillery, rockets, etc. may also exist.

Site characterization at small arms firing ranges involves soil and water analyses to determine the spatial distribution of contaminants. However, it is important to understand the physical processes and chemical reactions that affect lead distribution in the environment so that the potential for contaminant migration can be assessed. The following subsections will describe the important physical processes and geochemical reactions that govern lead mobility.

2.5.1 Physical Processes

Elemental lead from fragmented bullet slugs and shot can be transported as a particulate by the action of surface water, groundwater, and wind. Typically, the greatest lead concentrations are measured near impact sources (impact and lateral berms and shotfall zones). The action of water and wind could distribute lead particulates and lead-enriched soil down slope or along the prevailing wind direction.

When slugs and pellets are 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 carbonate. As pure solids, these oxidized compounds are nearly insoluble; however, physical abrasion of lead-rich metal fragments during erosion will release the oxidation products as dust into the environment and create particles yielding a larger surface area prone to breakdown and leaching.

2.5.2 Geochemical Reactions

The major reaction classes that govern lead transport and fate are

- dissolution-precipitation as a function of pH,
- dissolution-precipitation as a function of redox environment, and
- sorption-desorption reactions.

The extent to which these reactions occur depends somewhat on site conditions such as soil composition, extent of soil saturation, and soil organic content.

Lead compounds show the greatest aqueous solubility at the acidic (pH <4) and alkaline (pH >11) ranges. Under acidic conditions, elemental lead will dissolve, releasing a hydrated cation Pb^{2+}. Under alkaline conditions, elemental lead will dissolve, theoretically forming the dissolved hydroxide complex $Pb(OH)_3^-$ and ion-pair $Pb(OH)_{2\ (aqueous)}$. Water and soil with high carbonate alkalinity form the dissolved ion-pair $PbCO_{3\ (aqueous)}$. The scenario of lead transport as a dissolved hydroxide or carbonate ion occurs most frequently in contaminated calcic soils, carbonate sediments, or aqueous environments characterized by high dissolved carbon dioxide gas concentration. Also, as discussed under soil stabilization in Section 3, certain treatment approaches can contribute to this increased solubility.

When lead exists in a dissolved state, it can sorb to charged clay particle surfaces. In most natural sedimentary environments, clays carry a net negative surface charge. In a solution having neutral pH, dissolved cations are sorbed preferentially. Therefore, when dissolved lead exists as Pb^{2+} in dilute solution, transport can be attenuated by sorption to clays. These conditions occur in anoxic subsurface environments characterized by neutral to acidic pH, low dissolved solids concentrations, and low carbonate alkalinity. In contrast, when dissolved lead exists preferentially as an uncharged ion pair or negatively charged hydroxyl complex, transport can be enhanced because sorption is negligible (presence of two negatively charged surfaces). These conditions can occur over a range of redox conditions but require alkaline pH or high total dissolved solids or carbonate alkalinity concentrations.

2.6 Sample Collection and Analysis

After gathering and reviewing information on the past and current use of a SAFR subject to closure and the layout of the ranges, the next step in the site characterization is to develop a plan for sample collection and analysis to determine the vertical and horizontal extent and concentrations of the chemical constituents of concern in the environment. The site use and history will provide information regarding the type(s) and volume of ammunition used at the range. This information will indicate what the likely chemical constituents of concern are at the range and, consequently, what sampling procedures and analytical methods should be used to determine the concentrations of these constituents in the collected samples.

Decisions regarding where to gather samples will be based on the current and historical range layout and actual observation of where the bullets and/or shot pellets have been deposited. When formulating a sampling plan, one should walk the ranges and note where lead is deposited. Observations should be made of where the lead bullets or shot appear to be most concentrated and the rough vertical and horizontal limits of the area(s) where the bullets or shot are present. At trap, skeet, and sporting clay ranges, markings on trees and vegetation on the ranges may indicate the shot flight path.

During the walkover of the ranges, observations should also be made of any surface water bodies or wetlands that may be impacted directly by shot or bullets landing in these areas. Nearby surface waters or wetlands that could be receiving runoff from the areas of the ranges where shot or bullets are deposited should also be noted, and the sampling and analytical plan should investigate this possibility.

In situations where the area impacted by the lead shot or bullets may extend off the property owned and/or managed by the facility, property boundaries should also be identified during the site walkover, and the investigation of possible off-property impacts should be incorporated into the scope of the sampling and analytical plan.

2.6.1 Environmental Media of Concern

A SAFR site characterization should *initially* investigate all impacted or potentially impacted environmental media. While the focus of this document is the remediation of soils at SAFRs, a comprehensive site characterization requires the investigation of all affected or potentially affected environmental media of concern. For all ranges, the environmental media of concern in the initial phase of investigation include soil where the bullets or shot pellets are deposited and groundwater in these deposition areas. At those ranges where the bullets or shot are impacting surface waters or wetlands, either directly or potentially via surface water runoff/migration, the initial sampling should also assess these impacts through the sampling of sediment and surface water. Additionally, soil outside the areas directly impacted by bullets and shot should be assessed to determine whether lead or other chemical constituents have migrated as the result of runoff or windblown movement of soil particles. If the results of the initial investigation reveal that the chemical constituents of concern are limited to soil, then the sampling and analyses in subsequent phases of the investigation can be limited to assessing soil concentrations.

2.6.2 Sampling and Analytical Plan Objectives

Once a review of the range history and layout is completed and a walkover of the range to observe areas of bullets/shot deposition, a sampling plan can be developed. A sampling plan should present the objectives of the sampling and the approximate number, type (soil, groundwater, surface water, sediment) location, depth, etc. of the samples to be gathered. A sampling plan provides a guide for the assessment but is also subject to adjustments as the investigation proceeds and more is learned about range conditions.

Sampling objectives include

- identifying affected environmental media,
- determining the vertical and horizontal extent of contamination,
- determining background concentrations of the chemical constituents of concern (i.e., the concentrations that would be present in the absence of the range),
- defining areas where constituents of concern are concentrated (i.e., "hot spots"), and
- determining exposure point concentrations for the assessment of human and environmental risk.

Use of Field Screening

During the initial phase of the site characterization, field screening may be an effective way to define the boundaries of the area affected by the chemical constituents of concern, identify "hot spots" or source areas, and focus the scope of the investigation and sampling plan. Portable multi-element x-ray fluorescence (XRF) analysis, in particular, may be used to approximate[1] lead, arsenic, and other metallic elements *in situ* to establish contamination profiles and identify locations for collecting confirmatory samples for laboratory analysis. Since contamination patterns tend to be heterogeneous, the large number of data points gathered with *in situ* field screening can be a time- and cost-saving means of delineating contamination patterns.

Depending on the data quality objectives, an XRF instrument may be used to screen samples for subsequent laboratory analysis or may be used with USEPA Method 6200 to achieve the necessary precision and accuracy to quantify metal concentrations for use in risk characterization and remedial decision making.

Soil Sampling

The single most important step in any soil characterization or treatability study is sample collection and preparation. As such, it is not necessarily the size of the sample submitted, but rather the accuracy and representativeness of the sample compared to the whole volume of soil to be treated. This is difficult to achieve as lead contamination at small arms firing ranges presents the following unique challenges:

- Metal contaminants are present mostly as discrete particles ranging in size from intact bullets or shot to bullet fragments.
- Lead bullets striking the impact berms at high speed can actually vitrify on impact, forming “melts” on individual soil particles.
- Lead bullets at ranges that don’t have an active environmental stewardship plan or lead management plan may corrode over time. During rainfall, the surface corrosion may dissolve.

2.6.3 Sample Collection

Soil sampling procedures begin with appropriate sample collection. Soil samples from firing ranges are usually a heterogeneous mixture of matrix materials and contaminants. Individual granules of soil samples can be significant relative to the size of a subsample taken for analysis. Consequently, the analytical results can vary considerably depending on the particular group of granules selected in the subsample. Sample collection strategies should, therefore, be site-specific and a function of particulate metal distribution and soil gradation.

Several approaches for addressing the inherent variability of particulate metal distribution and soil gradation, as well as the vertical and horizontal distribution of contaminants between different types of firing ranges (e.g., rifle and pistol versus trap and skeet), have been developed (see Appendix B).

In soils where the distribution of contaminants is widespread and not easily predicted, a composite approach has been developed by Jenkins and others from the U.S. Army Cold

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[1] XRF, used for *in situ* analysis, is sensitive to particle size and distribution. XRF analysis should be confirmed with laboratory analysis.

Regions Research and Engineering Laboratory (USACRREL). This approach was initially developed for use in characterizing training range soils that had received indirect fire, with subsequent explosion of the rounds resulting in a heterogeneous distribution of explosives in the form of small particulates. The typical small arms firing range floor is similar in nature in that it receives indirect fire, and the particulates that are present are generally fragments from high-energy impacts and are dispersed in a heterogeneous manner.

Since 1999, this approach has been successfully implemented at numerous small arms firing ranges. At Camp Edwards, located on the Massachusetts Military Reservation, this approach was used for both training ranges and small arms firing range floors. Collection began with dividing the area of interest into grids measuring 22 x 22 feet. Five subsamples were spaced in an “X” pattern. Each of the four corner subsamples was spaced 5.5 feet from the nearest grid edges. The center subsample was located at the center of the grid. Sampling intervals may vary but are usually 0–6, 6–12, 12–24, or 24–36 inches below ground surface (bgs), based on the location within the range and anticipated depth of penetration by projectiles.

The subsamples were then composited. Each composited sample was placed in a clean cement mixer and mixed for 5 minutes to maximize homogenization. Alternatively, the composited sample may be rolled on a plastic high-density polyethylene tarpaulin from each of the corners to the middle of the tarp, repeating the rolling process three times. In either case, homogenization equipment is decontaminated between samples.

For berm areas, however, the particles are concentrated in bullet pockets and can be found at depths exceeding several feet. In these areas, trenching through the berm will provide a more appropriate sample, with the added benefit of being able to visually inspect the berm core at depth. Samples are collected from the trench walls in this case and composited as outlined above.

2.6.4 Preparation of Soil Samples for Analysis

Preparation of soil samples must address the range of materials that can be found in a sample. Various plant parts, insects, rocks, and other materials are found in soil and must be addressed in collecting any soil sample. Soil is composed of a mixture of sand, silt, and clay, along with humified organic materials. Fauna, flora, and anything large enough to be identified by the naked eye are usually excluded in taking a sample. Engineering, agriculture, and the environmental fields have long recommended removing extraneous materials from a sample before submitting the soil to laboratory analysis. Removal is often accomplished visually, but many disciplines have adopted the use of a #10 sieve to separate soil from other materials.

The variability of measured chemical concentrations in soil has been noted in many professional fields. Some of the variability is due to the nature of collecting soil samples, but most variability is an inherent property of the soil itself. Each soil grain-size fraction exhibits its own range of physical and chemical properties, which causes different amounts of interaction with substances in the soil pore water. Differences in surface area and surface charge can cause significant differences in the chemical concentrations found in various soil-size fractions. Previous work indicates that measured metal contamination, for example, can vary by over two orders of magnitude between the silt-clay fraction (minus 200-mesh) and medium sand (10-mesh by 40-mesh) alone. Consequently, one sample that contains more minus 200-mesh will generate a higher total metal result than a sample containing more 10-mesh by 40-mesh soil and so forth. Please refer to the Air Force Center for Environmental Excellence's *Technical Protocol for Determining the Remedial Requirements for Soils at Small Arms Firing Ranges* (2000) for additional detail.

While many current analytical methods rely on using only soil that has passed uncrushed through a 30-mesh sieve as the source for analytical tests, some controversy exists in the field as to the best method(s). Differences in sample preparation protocols include the designation of the size of sieve to use or whether to use a sieve at all; and on the degree of disaggregation prior to sieving. Therefore, the recommendation of a specific sample preparation method may be misleading. The choice of a method should result in a sample that is representative of the site and its environment, addresses the concerns that led to the need for sampling, and is agreeable to the regulatory community and other parties involved in the evaluation. (If you want to make sure a treatment meets the regulatory requirements for average concentrations in soil, you may want to get as much homogeneity as possible in your sample. However, if you want to make sure a treatment process is degrading/removing the contaminant, you may NOT want to disaggregate your sample but instead get more samples to see if there are any "particle" hits.)

2.6.5 Soil Sample Analysis

Standard USEPA SW-846 Method 3051 is used for digestion of samples for total metals analysis. The digestates can then be analyzed by flame AA or by ICP (SW-846 Standard Method 6010).

2.7 Risk Assessment

Risk assessment provides an evaluation of the potential threat to human health and the environment from contaminants in environmental media and can provide a basis for determining the necessity for, and extent of, remedial action.

Detailed guidance on evaluating potential human health impacts are provided in:

- USEPA's *Risk Assessment Guidance for Superfund* (RAGS), EPA/540/1-89/002 (December 1989)
- American Society for Testing and Material's (ASTM) *Risk-Based Corrective Action* (RBCA) (ASTM, 1995)

Detailed guidance on evaluating potential ecological impacts is provided in:

- USEPA's *Ecological Risk Assessment Guidance for Superfund* (ERAGS), EPA/540-R-97-006 (August, 1997)

In addition, many states have developed their own guidance, which should be consulted when conducting human health and ecological risk assessments.

In general, a risk assessment is composed of the following components:

> **Conceptual Site Model**: The conceptual site model (CSM) identifies potential sources of constituents of interest, potential migration routes for constituents, and potential receptors and exposure pathways. The CSM provides the foundation for the human health or ecological risk assessment.
>
> **Identification of Constituents of Interest**: Constituents detected in surface water, sediment, and fish tissue are compared to background concentrations and conservative, default risk-based screening values to determine which constituents should be retained for quantitative risk characterization.
>
> **Calculation of Constituent Intakes**: For all receptors with complete exposure pathways, constituent intakes (i.e., doses) are estimated. Intakes are calculated for noncarcinogenic and carcinogenic effects for applicable routes of exposure.
>
> **Calculation of Exposure Point Concentrations**: To determine constituent intakes for each receptor, exposure point concentrations are calculated for each constituent of interest in each medium. Exposure point concentrations may be calculated directly from measured concentrations or estimated using fate and transport models.
>
> **Constituent-Specific Parameters**: Constituent-specific toxicological parameters (cancer slope factors and reference doses) must be identified in order to calculate risk. For human health risk, these values are obtained from the Integrated Risk Information System (USEPA, 2000) or the Health Effects Assessment Summary Tables (USEPA, 1997a). Additional constituent-specific parameters (e.g., absorption factors) may also be required. Constituent-specific toxicological parameters for ecological receptors may be obtained through dose-response experiments or from various literature sources.
>
> **Risk Characterization**: The calculated intakes are combined with chemical-specific toxicological parameters to determine cancer risks and/or hazard indices for each receptor and exposure pathway.
>
> **Uncertainty Analysis**: The uncertainty analysis reviews the key assumptions that were incorporated in the risk assessment and the potential effect that these assumptions may have on the results.

Risk assessment frameworks allow for the incorporation of site-specific inputs by adopting a tiered system of evaluating risk. Earlier tiers of the risk assessment process (i.e., screening level) compare contaminant concentrations to background concentrations and/or generic risk-based concentrations, which represent a conservative estimate of risk. Subsequent tiers in the process (i.e., baseline risk assessment) allow the use of more site-specific information to fine-tune the risk evaluation.

While RAGS, RBCA, and state risk assessment guidance are used to evaluate potential risks to humans posed by most contaminants at SAFRs (i.e., metals and polycyclic aromatic hydrocarbons, or PAHs), the evaluation of risk to humans from lead is accomplished by two separate methodologies that have been created by USEPA's Technical Review Workgroup for Lead (TRW):

- Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) for residential exposures (*Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children.* February 1994), and

- Adult Lead Model for nonresidential exposures (*Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil*. December 1996).

TRW is an interoffice workgroup convened by the USEPA Office of Solid Waste and Emergency Response/Office of Emergency and Remedial Response. The two lead models, and information pertaining to them, can be found on the TRW Web site (www.epa.gov/superfund/programs/lead).

The IEUBK model relates soil-lead concentrations to blood-lead concentrations in children for long-term exposure to lead in a residential setting and can be used to determine target cleanup levels for residential use. The Adult Lead Model relates soil-lead concentrations to blood-lead concentrations in the developing fetus of an adult woman who has potential exposure to the site and can be used to determine target cleanup levels at nonresidential (i.e., commercial and industrial) sites.

Based on these models, the generic screening level for lead in soil is 400 mg/kg for residential sites and 1000 mg/kg for industrial sites. USEPA and some states have developed generic screening levels for other contaminants at small arms firing ranges. For example, USEPA Region 3 Risk-Based Concentration Tables (USEPA, 2002a) and USEPA Region 9 Preliminary Remediation Goals (USEPA, 2002b) are often used as sources of generic screening levels.

2.7.1 Application of the Human Health Risk Assessment Process to Small Arms Firing Ranges

While most of the general risk assessment process applies directly to small arms firing ranges, a few of the steps can be modified to address the special circumstances of these sites.

Conceptual Site Model

Figure 2-5 presents an example conceptual site model developed by the Air Force Center for Environmental Excellence (AFCEE) to focus the risk assessment at small arms firing ranges. Once the source(s) and release mechanisms have been identified, an analysis of the environmental fate and transport of the chemicals can be conducted. This analysis considers the potential migration, transformation, and transfer mechanisms to provide information on the potential magnitude and extent of contamination. From this information, the actual or potential exposure points for receptors can be identified. The focus of this effort should be on those locations where actual contact with the compounds of potential concern (CoPC) will occur or are likely to occur. Last, potential exposure routes that describe the potential for the CoPC to enter the receptor's body are identified and described.

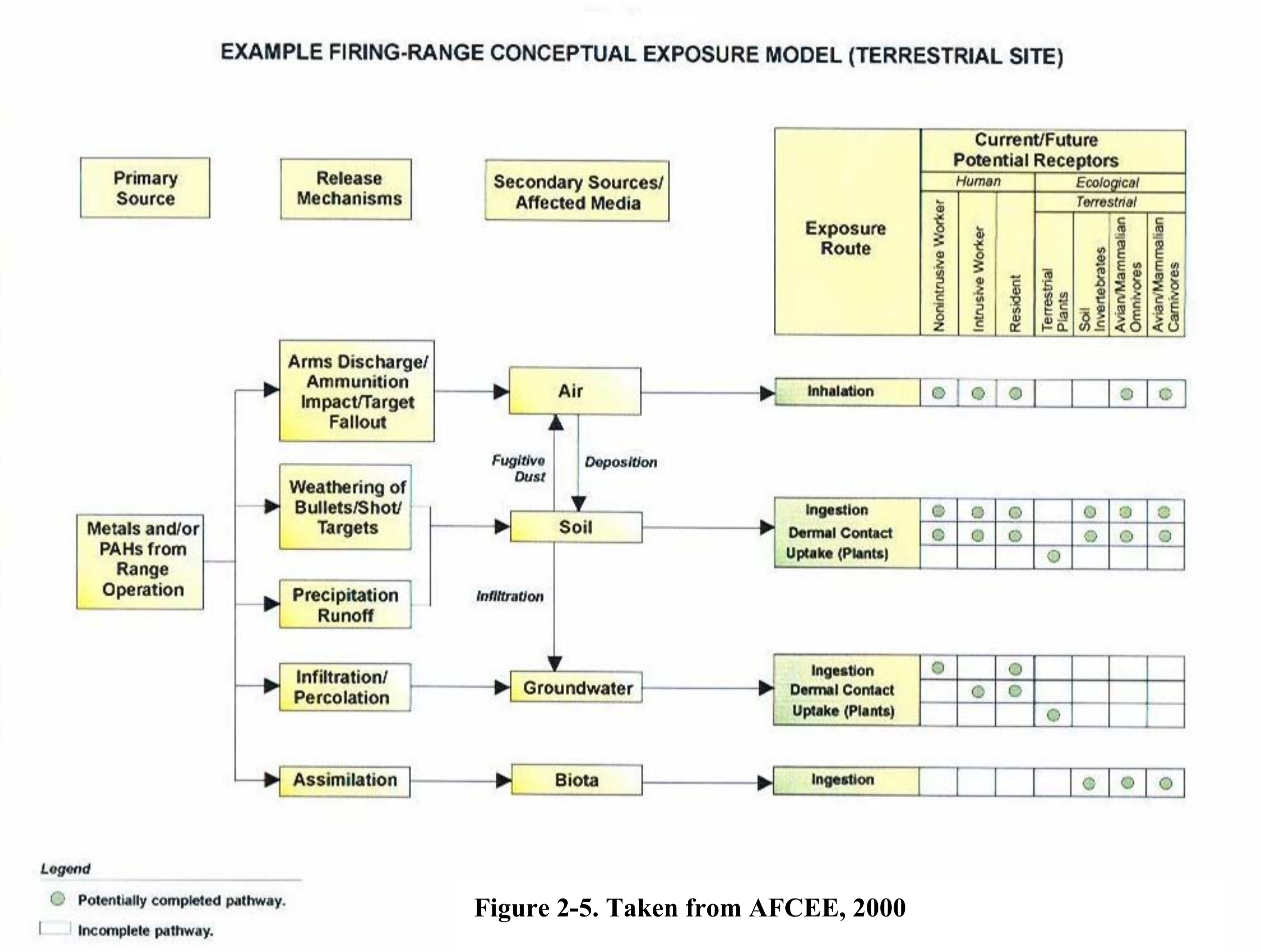

Figure 2-5. Taken from AFCEE, 2000

Contaminant Identification

While the evaluation of a hazardous waste site involves consideration of a full target analyte list of chemical parameters, the focused nature of a small arms firing range provides some opportunity to focus on a few selected constituents. Unless otherwise indicated in the site history, the use of small arms firing ranges is limited to projectiles of small caliber (less than 0.50 caliber). These projectiles are overwhelmingly lead or copper-jacketed lead with a few being composed of some other metal, usually steel, or a polymer. Other CoPCs include antimony, arsenic, copper, iron, tin, zinc, and PAHs (see Table 1-1 for a complete list of CoPCs and sources at SAFRs). However, the primary CoPC at theses sites is usually lead with potential contribution from copper or arsenic. Peddicord and LaKind (2000) found no adverse effects to human receptors due to PAHs at a SAFR.

The primer is generally composed of a metallic fulminate, styphnate, or azide compound (usually lead) and a propellant (granular, smokeless powder or black powder). Modern propellants are composed of nitrocellulose or nitrocellulose and nitroglycerine mixtures. Both the propellants and the primer are rapidly burning materials that leave little residue as either decomposition products or uncombusted compounds. Additionally, both the original compounds and the decomposition products are mostly analyzed as common soil compounds, which are difficult to evaluate (organic carbon, CO_2, nitrates, etc.).

Exposure Assessment

The exposure assessment is highly dependent on the current and future land use expected for the site. When a small arms firing range is to continue its operation, the risk assessment should be based on the range's impact on groundwater with no quantitative ecological risk assessment, unless a migratory pathway away from the range can be established. The reasons for this type of assessment are not obvious. If the range is to continue in use, metallic deposition in the backstop/berm area will continue. The only human receptors will be site workers, who are covered by the exposure standards of the Occupational Safety and Health Administration (OSHA). For safety, site visitors are not allowed near the backstop/berm area, thus eliminating their exposure. Ecological concerns are addressed by the nature of the range operation (i.e., a commercial operation, which does not support wildlife).

However, for small arms firing ranges that will be discontinued and the site re-used for other purposes, the identification of future land use (i.e., residential, commercial/industrial, or park/recreation area) needs to be identified, and the appropriate receptors should be evaluated for potential risk (i.e., child or adult residents, adult workers, construction/utility workers, recreational users, or ecological receptors).

2.7.2 Ecological Risk Assessment

During the development of the risk assessment, it may be necessary to evaluate the potential for impacts to ecological receptors from exposure to metals and organics through preparation of an ecological risk assessment (ERA). In certain circumstances, the focus of potential remedial actions at a range may be either substantially or solely driven by the results of the ERA. As opposed to a human health risk assessment with its single receptor and limited number of exposure scenarios, the preparation of an ERA requires a more complex assessment of multiple receptors of different taxa and a variety of potential exposure mechanisms.

An ERA is an iterative process for evaluating the likelihood that adverse impacts may occur, or are occurring, as a result of exposure to one or more stressors. Ecological impacts may occur if the stressor has the inherent ability to cause one or more adverse effects, and the stressor co-occurs with or contacts ecological components that include diverse organisms within a population or community. The ecological communities that may potentially be affected include terrestrial ecosystems exposed to contaminated soils and aquatic and wetland ecosystems exposed to contaminated surface water and sediments. The ERA process is designed to help identify environmental problems, establish priorities for resolving those problems, and provide a scientific basis for possible actions.

ERAs most commonly conform to the framework described in USEPA's *Framework for Ecological Risk Assessment* (EPA/630/R-92/001) and *The Guidelines for Ecological Risk Assessments* (Federal Register, Vol. 63, No. 93, p. 26846), which divide ERAs into three stages: problem formulation, analysis, and risk characterization. In addition, several states have developed their own ecological risk assessment guidance.

Problem formulation is the process by which a preliminary hypothesis about why ecological effects may be occurring is developed. During the problem formulation stage, a scope of work for conducting the risk assessment is defined, usually through the completion of a conceptual site model. The analysis phase is the technical evaluation of data to reach conclusions about ecological exposure and the relationships between the stressor and ecological effects. The risk characterization phase uses the results of the analysis phase to estimate risk to the receptor endpoints identified in the problem formulation phase.

While the term "risk" is used in this section, the risk characterization mathematically calculates a level of concern to be taken into account in any remedial decisions. This numerical value is not an absolute determination of the risk of adverse effects to the receptor. It is a relative comparison of an estimate of the exposure to the receptor in the field with a safe laboratory-derived reference dose for the same or different species. Risk to an ecological receptor or receptor community can only be established by direct measurements of detrimental effects in the field.

For ERAs completed at SAFRs, more detailed guidance can be found in USEPA's *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (EPA 540-R-97-006). This guidance expands this framework into a multistep process by which a greater level of ecological scrutiny is placed, as needed, at each of the steps.

For the majority of sites, an ERA will not need to proceed beyond a screening-level assessment. The screening-level assessment can narrow the scope of possible subsequent assessment activities by focusing on those aspects of the site that constitute realistic potential risks. Additionally, screening-level assessments serve to identify data gaps in both the evaluation of chemicals and in the identification of matrices of concern. Screening-level assessments will generally consist of a straightforward comparison of concentrations of metals and organics in surface soils, surface water, and sediments (as appropriate) to relevant benchmarks for the determination of potential risks. Site specificity is included with respect to potential receptors and potential exposure pathways. Additional steps in an ERA are pursued only if potential risks are noted and it is necessary to refine those risk estimates for purposes of remediation. An example of an ecological risk assessment at a SAFR can be found in Peddicord and LaKind (2000).

2.7.3 Ecological Risk Assessment State Survey

Interdependent risk assessments often are conducted for human and ecological receptors potentially exposed to contaminants in range media. While differences in methods and assumptions justify separate analyses, several considerations are common to both types of risk assessments. Aside from the federal requirements under RCRA and Superfund, many states have variations under authorization programs such as RCRA or state-developed remediation cleanup or mitigation programs. In an attempt to understand the potential variability, ITRC states were asked the following survey question:

> "When permitting remediation of a small arms firing range, do you require an ecological risk assessment in addition to a human health risk assessment? Please comment and explain your answer."

The following states replied to the survey question as follows:

Florida — "Florida has not required an ecological risk assessment for a small arms range remediation. They will evaluate a site before deciding if an ecological risk assessment is required. The Florida Center for Solid and Hazardous Waste Management has also developed *Best Management Practices for Lead at Outdoor Shooting Ranges*."

Kansas — "Kansas has no specific requirements for an ecological risk assessment under state guidance; however, small arms ranges under CERCLA within the state are required to have an ecological risk assessment performed."

New York — "New York does not generally use ecological risk assessments. For range sites (as well as other sites that have potential eco impact), we start with a Fish and Wildlife Impact Analysis. If the findings of this analysis are positive, we then go further and require additional work such as tissue analysis. When selecting remedies, consideration is given to whether the alternatives will cause more harm than good."

New Jersey — "New Jersey has cleanup standards that are health-based. As such, they do not require risk assessments. For ecological concern, the consultants for the RP are required to assess the need (for an ecological risk assessment) based on the following three criteria:

- What are the contaminants? Are they mobile, and could they present a threat?
- What are the potential receptors in the vicinity of the site? Could they potentially be impacted?
- What are the transport mechanisms? Is there a general pathway that could potentially result in impact?

Based on the answers to these questions, the RP must determine if there is a reasonable potential for ecological impact to occur. NJDEP reviews the results of the survey and either concurs or requires further work."

Oklahoma — "Oklahoma has no experience permitting remediation activities at small arms firing ranges; however, they make site-specific determinations on the need for an ecological risk assessment after the initial request is made."

Oregon — "Oregon environmental cleanup rules require that all removal and remedial actions be protective of human health and the environment. 'Acceptable risk levels' are defined in the rules for both individual ecological receptors and for populations of ecological receptors. Thus, for any site requiring remediation, some level of ecological risk assessment must be performed. However, Oregon's rules provide for a four-tiered approach to ecological risk assessments as follows:

• Level I	Scoping
• Level II	Screening
• Level III	Baseline
• Level IV	Field baseline

"At many sites, only a level I assessment is required. A level I assessment is a conservative, qualitative determination of whether or not there is any reason to believe that ecological receptors and/or exposure pathways are present, or potentially present, at or in the locality of the facility (i.e., the area where contamination exists and is reasonably likely to migrate, in the absence of any remedial action). Scoping is intended to identify, and eliminate from further study, sites that are obviously devoid of ecologically important species or habitats and/or where exposure pathways are obviously incomplete."

Pennsylvania — "Remediation of a small arms range would follow the Pennsylvania Act 2 regulations if any kind of liability relief is being sought. With respect to the standard chosen, ecological receptors would need to be addressed in some way. Under the statewide Health Standard Generic Numeric cleanup values for anywhere in the state, the ecological screen exists. If the site does not pass the screen, a more involved assessment is required. Under the site-specific standard, ecological risk assessment is required. There is no ecological screen under the site-specific standard. We actually have no requirements specific to regulation of small arms ranges; however, we are going to prepare 'guidance' primarily citing USEPA's Best Management Practices Manual."

Tennessee — "Tennessee has not dealt with remediation of small arms ranges. Most likely they would not require an ecological risk assessment unless there are strong indications that a wetland or other area is being, or potentially could be, impacted."

2.7.4 Measuring Bioavailability for Determining Risk

Metals and organic compounds at SAFRs may come into contact with human and other receptors through the ingestion, dermal contact, or inhalation of soils exposure pathways. The amount of these compounds in soils that is used to assess risk and determine cleanup levels is determined from analytical methods that extract the total concentration in soil. However, in reality only a fraction of these compounds will generally be "available" to the relevant receptors. This fraction is termed the bioavailable amount of the compound. USEPA defines bioavailability as "the fraction of the total amount of material in contact with body portal-of-entry (lung, gut, skin) that enters the blood" (USEPA, 1999). Bioavailability can further be defined as absolute or relative, where

- Relative bioavailability is the amount of a substance entering the blood via a particular route of exposure (e.g., gastrointestinal) divided by the total amount administered (e.g., soil lead ingested).

- Absolute bioavailability is the comparative bioavailability of different forms of a chemical or for different exposure media containing the chemical relative to the bioavailability of a standardized reference material (e.g., bioavailability of soil lead relative to its bioavailability from soluble lead acetate).

Absolute bioavailability can be incorporated within the risk assessment process by adjusting the fractional relative absorption factor (RAF) in the chronic daily intake (CDI) calculations of the exposure assessment. A good review of the bioavailability of metals in soils can be found in the National Environmental Policy Institute's (NEPI) document entitled *Assessing the Bioavailability of Metals in Soil for Use in Human Health Risk Assessments* (NEPI, 2000; www.nepi.org). Since lead is generally the CoPC at SAFRs, lead bioavailability is discussed below.

Lead Bioavailability

Lead is generally the compound of most concern at SAFRs. Studies conducted on SAFR sites indicate that lead from ammunition may contribute to soil in any of three forms: metallic lead, Pb^{+2} (dissolved from the crust of the ammunition), and as a variety of oxidized compounds (largely hydroxycarbonates, carbonates, and sulfates). Ingestion of fragments of lead ammunition may be the cause of children exhibiting pica behavior, although metallic lead is largely insoluble (USEPA, 2000b). Lead speciation within the soil matrix, soil type, mineralogy, and soil particle-size have been shown to affect soil-lead bioavailability (USEPA, 2000a).

Bioavailability of metallic lead has been shown to decrease with increasing particle size (Barltrop & Meek, 1979). There also is evidence to suggest that smaller soil particles (e.g., <100 – 250 μm) are more likely to be incidentally ingested than larger particles because the particles adhere more readily to the skin (Druggan, et al., 1985; Bornshire, et al., 1987; Driver, et al., 1989; Shepard and Everden, 1994; Duff and Kissel, 1996; and Kissel, et al., 1996a). Studies conducted on 20 soil-lead samples found varying levels of bioavailability, as shown in Table 2-1. Therefore, lead bioavailability at SAFR sites may differ depending on the interaction of the ammunition with chemical reactants in the soil.

Generally, soils should be sieved to < 250 um (60-mesh) prior to measuring bioavailability and also as a recommended input to the IEUBK and Adult Lead Models (USEPA, 2000a). Even though 60-mesh may yield the most representative results, the AFCEE studies show no measurable difference in results screened at 10-mesh at the time of sample collection (AFCEE, 2000). Bioavailability of lead from soils is currently utilized in the IEUBK and Adult Lead risk assessment methods that have been created by USEPA's Technical Review Workgroup for Lead (TRW).

The IEUBK Model relates soil-lead concentrations to blood-lead concentrations in children for long-term exposure to lead in a residential setting and can be used to determine target cleanup levels for residential use. Bioavailability within the IEUBK Model is set at a default estimate of 30% as an absolute value. This number is derived from the estimation of 50% bioavailability of soluble lead in water and food and presumes that the relative bioavailability of lead in soil is 60%. The absolute bioavailability of soil lead is therefore 50% x 60% = 30% (USEPA, 1999).

The Adult Lead Model relates soil-lead concentrations to blood-lead concentrations in the developing fetus of an adult woman who has potential exposure to the site and can be used to determine target cleanup levels at nonresidential (i.e., commercial and industrial) sites. The default estimate of bioavailability of lead in the Adult Lead Model is 12%, based on an absorption factor for soluble lead in adults of 20% and the relative bioavailability of lead in soil compared to soluble lead of 60% (20% x 60% = 12%, USEPA, 1996).

Potentially Lower Bioavailability (RBA < 25%)	**Intermediate Bioavailability (RBA = 25% to 75%)**	**Potentially Higher Bioavailability (RBA > 75%)**
Galena (PbS) Anglesite ($PbSO_4$) Pb (M) Oxides Pb Fe (M) Sulfates Native Pb	Pb Oxide Pb Fe (M) Oxides Pb Phosphate Slags	Cerrusite = $PbCO_3$ Pb Mn (M) Oxides

Table 2-1. Potential Bioavailability of Various Lead Minerals

RBA = relative bioavailability, M = Metals
(From USEPA, 1999)

Site-Specific Measurement of Bioavailability

Animal dosing studies (i.e., *in vivo* bioassays) are the only approved methods to measure soil-lead bioavailability for application to a site-specific risk assessment. Currently, USEPA indicates that the juvenile swine model may be the best method for determining site-specific bioavailability of lead; however, other *in vivo* studies using different species may be accepted on a case-by-case basis (USEPA, 1999). These studies have currently not been applied to SAFRs to determine site-specific bioavailability (personal communication with the Technical Review Workgroup for Lead).

A lead bioavailability test using juvenile swine has been developed to evaluate relative lead bioavailability (Casteel, et al., 1997). In the juvenile swine model, swine are dosed with differing amounts of either lead in soil or lead acetate. The swine are dosed twice daily to mimic childhood lead exposure. Blood samples are collected and analyzed for lead during the study; and at the end of the study, samples of blood, bone, and liver and kidney tissue are collected and analyzed for lead. The resulting data are used to estimate relative lead bioavailability by comparing lead in blood and tissues from the swine receiving soil lead relative to the swine receiving lead acetate. Studies conducted using the juvenile swine test indicate relative lead bioavailability estimates from soil between less than 0.01 and 0.90. These studies support USEPA's use of 30% lead absorption (relative bioavailability of 60%) from soil as a default assumption for child lead ingestion in the IEUBK Model (NEPI, 2000).

To determine bioavailability from lead ingestion in adults, a stable lead-isotope technique was utilized on adult humans. Results indicate that between 8.1% and 26.2% of the administered dose of lead was absorbed. When the lead was ingested after eating, the absolute lead bioavailability was reduced to between 1.7% and 2.5% (Maddaloni, et al., 1998). These results support the lower lead bioavailability value seen in USEPA's Adult Lead Model.

In vivo tests to determine lead bioavailability are time-consuming and expensive and may create ethical concerns. Therefore, *in vitro* methods are being developed to measure metal bioavailability as a function of the dissolution of lead and other metals within a simulated gastrointestinal tract environment (Ruby, et al., 1996). In these methods, metal salts or soil metal are incubated in a low-pH solution to mimic residence time in the stomach. The pH is then increased to a neutral range to mimic residence time in the small intestine. The fraction of lead that dissolves during these incubation phases is the bioaccessible fraction (i.e., the amount that is soluble and available for absorption). A correlation between the juvenile swine model and the stomach phase of the *in vitro* test indicated that lead dissolution in the acidic stomach environment of the *in vitro* test is predictive of relative lead bioavailability in the juvenile swine test (NEPI, 2000).

A refined *in vitro* test, called the physiologically based extraction test (PBET), has been developed by the Solubility/Bioavailability Research Consortium (SBRC), based on stomach and intestinal dissolution of lead. Lead bioaccessibility from soil as determined by the PBET has been shown to be well correlated with lead bioavailability from soil as determined by a rat model and a swine model (NEPI, 2000). A formal validation of the PBET is currently ongoing; however, USEPA currently considers that there is insufficient evidence for using these tests to quantify lead bioavailability (USEPA, 1999).

The dermal and pulmonary bioavailability of lead is generally not utilized in risk assessments. It is assumed that absorption of inorganic lead compounds through the skin is negligible in comparison to the oral or inhalation routes (ATDSR, 1993). The bioavailability of lead from inhalation exposure is very dependent on particle size, where smaller particle sizes appear to contribute a greater fraction of inhaled lead deposition within the lungs (NEPI, 2000).

Arsenic Bioavailability

In vivo studies on arsenic bioavailability from soil indicate a reduced absorption of arsenic compared to soluble forms and suggest a relative bioavailability between 0.1 and 0.5 (NEPI, 2000). Soil arsenic bioaccessibility has been shown to correlate well with soil arsenic bioavailability using a monkey model, a rabbit model, and a swine model (NEPI, 2000). However, the correlations between *in vitro* and *in vivo* studies for arsenic are generally not as good as those demonstrated for lead.

Research and Development – Future Needs

Several areas of research and development have been identified by the In-Place Inactivation and Natural Ecological Restoration Technologies (IINERT) Soil-Metals Action Team, part of the Remediation Technologies Development Forum (RTDF, www.rtdf.org):

- Develop a more thorough understanding of the factors that control soil-metal bioavailability to humans, which should include the biological, chemical, and physical factors that affect bioavailability.

- Develop and validate simple *in vitro* techniques that can be used to assess soil-metal bioavailability to humans. These simple techniques should be well correlated to appropriate human or animal (e.g., pigs and rats) model surrogates.

- Develop correlations between soil components (i.e., metal species, nonmetal-containing components) and the soil-metal bioavailability for determining the short- and long-term stabilities of soil-metal components.

- Develop treatment technologies and processes for adding materials to metal-contaminated soils that induce the formation of less bioavailable metal forms, providing a practical approach to in-place inactivation.

3.0 TECHNOLOGY OVERVIEW AND APPLICATION

A variety of technologies are appropriate for remediating lead contamination at small arms firing ranges. The choices are dependent upon characteristics of the site, costs, length of time allowed for remediation, land availability, and, foremost, future land use. The technologies all have proven records of success. With proper design of the appropriate technology or system of technologies, successful remediation can be achieved.

3.1 Dig and Haul

The baseline approach on closure of firing ranges is to excavate the soil, load the soil onto over-the-road trucks with end dumps, and transport the soil to an appropriate landfill. Before the approach is selected, the contractor/owner will need to confirm whether the soil is RCRA hazardous by testing appropriate constituents using the Toxicity Characteristic Leaching Procedure (TCLP) method. The soil is RCRA hazardous waste according to the following criteria:

Element	RCRA TCLP Requirements
As	≥ 5.0 mg/l
Ba	≥ 100 mg/l
Pb	≥ 5.0 mg/l

Table 3-1. RCRA Regulatory Concentrations for TCLP Testing

As shown, if any of the listed metals fall within the stated RCRA concentration criteria for specified metals, then the soil is considered hazardous and must be managed as a hazardous waste. Furthermore, the soil can be considered characteristically (reactivity) hazardous if it contains live rounds. An actual site remediation may generate both hazardous and nonhazardous wastes and, thus, use both landfill types.

However, with the technologies described in the following sections, the owner/operator has alternatives for closure of their firing range containing hazardous soil. These technologies have been implemented on other site closures and may reduce liability for the generator/owner because the soil will no longer have hazardous waste characteristics.

3.2 Soil Washing/Particle Separation

The soil-washing process uses mineral processing techniques and procedures to recover particulate contaminants as refined “products.” The operation is dust-free, and in the case of ranges, the recovered metal is considered “scrap metal” per 40 CFR 261.1(c)(6). Under this citation, scrap metal is classified as a “recyclable material,” which is not regulated or manifested. As a rule, the site and the excavated material is surveyed for live UXO prior to treatment, and live small arms rounds are segregated from other recovered metals as part of the soil-washing process, prior to shipment of metal for recycling.

Soil washing also classifies soil fractions by both size and density. Through their affinity for soil fines and organic matter, sorbed contaminants, if present, can be partitioned, and the concentrated contaminant-bearing material then segregated from the clean soil fractions for subsequent treatment or disposal. Hence, the volume reduction of material requiring further treatment is a function of the organic/fines content of the soil.

For sandy soils, a dry-screening step can possibly be substituted for the wet-screening techniques for physical sizing. While this is not a dust-free operation, simple misting can help minimize the dust. Dry processing can offer potential savings over wet-screening steps if the soil is amenable to dry processing, and this needs to be evaluated as part of a treatability study.

3.2.1 Process Description

While the concept of soil washing is over 100 years old, its application in remediating metals-impacted soils began in the early 1990s. Since that time, the process has been refined and the equipment streamlined to provide higher throughputs from a physically smaller plant as described in subsequent sections. The results are more efficient operations with reduced processing costs. Following is a description of major unit operations. These operations are selected and/or configured on an as-needed unit-operations basis as determined by the treatability study.

3.2.2 Physical Sizing

The physical-sizing process uses sequential wet-screening steps, the first of which is deagglomeration. Wet screening provides dust-free operation and sharp particle-size fraction cuts. For each screening step, "plus" and "minus" fractions are generated, with actual cut points based on the treatability study data. The goal of wet screening is to partition the particulate metal contamination into narrow-size fractions to facilitate effective gravity separation and to partition soil particles containing organic contaminants into the smallest size fraction for subsequent classification.

For free-flowing sandy soils with little oversize material other than spent projectiles, simple dry screening may be sufficient to recover the bullets in a condition suitable for recycling. The practical lower limit for screen size is 3/8 to 1/4 inch. For soils containing a measurable clay content, significant volumes of soil in the screen reject or plus-size fraction, or for soils requiring particulate removal below 1/4 inch, dry screening is generally not feasible.

3.2.3 Soil Classification

Sand screws and/or hydrocyclones are used to classify soil through segregation of the contaminant-bearing material from the clean sand and gravel fractions. With sand screws, water flow coupled with screw rotational speed are used to set the actual cut points. For hydrocyclones, flow rates coupled with apex size determine the cut points. The goal of classification is to minimize the volume of soil requiring subsequent treatment while maximizing the output of clean sand and gravel.

3.2.4 Gravity Separation

When particulate contaminants are the same size as the surrounding soil particles, gravity separation is used to remove the particulates from the same-sized soil matrix. Elutriation and jigging are used for soil fines removal and gross particulate removal, respectively. Elutriation uses water flow over weirs to separate soil fines from larger sand particles. Jigging uses differential settling in water to separate heavy, metal particles from same-size but lighter sand/gravel particles. This approach has seen successful use in both commercial mineral processing and range remediation.

3.2.5 Magnetic Separation

To recover tramp iron and other spent ferrous metal debris, self-cleaning magnets are suspended over the intermediate product conveyors to automatically remove tramp iron and other ferrous metals from the product stream after the initial high-pressure wash. The iron is then deposited in a bin for subsequent recycling.

3.2.6 Dewatering and Water Treatment

To close the loop on water consumption, process water is recycled within the plant. A clarifier and dewatering screen may be used in series to segregate/dewater heavy humates and condition the fines-slurry for subsequent dewatering using a belt filter press. Sand and carbon filtration follows as a polishing step for final rinse spray bars, if required. This enables the counter-current reuse of process waters while minimizing water consumption and associated disposal costs.

3.2.7 Humate Removal

A static organic removal screen is incorporated after each elutriation/classification step to recover the "floatable" humates in the aqueous stream. In addition, a high-frequency vibratory screen may be used after the initial fines dewatering step to remove the "heavy" humates from the fines stream prior to belt filter press dewatering. All of the recovered humates are containerized for subsequent treatment and/or disposal.

3.3 Soil Stabilization

Stabilization/solidification has often been used to change the hazardous characteristic of firing range soil prior to long-term management or to control the solubility of metals in range soil for groundwater protection. Stabilization/solidification has historically been used to describe several unique processes by which metal-bearing waste can be treated to remove hazardous characteristics. More recently, those active in the remediation field have recognized that there is an important distinction between the two terms.

Solidification generally refers to adding pozzolanic material to a waste to reduce permeability and surface area. These pozzolans are usually alkaline materials, which can often increase the solubility of metals in many disposal environments.

The most common form of solidification is a cement process. It simply involves the addition of cement or a cement-based mixture, which thereby limits the solubility or mobility of the waste constituents. These techniques are accomplished *in situ* by either injecting a cement-based agent into the contaminated materials or *ex situ* by excavating the materials, machine-mixing them with a cement-based agent, and depositing the solidified mass in a designated area. The goal of this process is to limit the spread of contaminated material via leaching. The end product resulting from the solidification process is a monolithic block of waste with high structural integrity. Types of solidifying/stabilizing agents include Portland; gypsum; modified sulfur cement, consisting of elemental sulfur and hydrocarbon polymers; and grout, consisting of cement and other dry materials such as acceptable fly ash or blast furnace slag. Processes utilizing modified sulfur cement are typically performed *ex situ*.

Stabilization, or chemical treatment as it is often referred to, is different in that the reagents added to the contaminated soils form less soluble compounds while controlling pH in a range of minimum solubility. Because less soluble compounds are formed, stabilized waste is often considered more protective of groundwater.

Heavy-metal contamination in soils is widespread in the United States and other parts of the world. The most common remedy for lead- (Pb) contaminated soils has been to mix the soils with chemical binders such as Portland cement and to relocate them to landfills, safely away from receptors. Portland cement works by increasing particle size and imparting the resulting material with a high buffering capacity in the alkaline pH range. The large particles and alkaline pH buffering capacity that result from the stabilization process reduce the amount of contaminant that is extracted by laboratory leaching methods, including regulatory tests such as the Toxicity Characteristic Leaching Procedure (TCLP) and the Synthetic Precipitation Leaching Procedure (SPLP). But this stabilization process can increase leaching in "real-world" disposal environments when the acid from leaching tests is not present to moderate the pH of the treated matrix.

The chemical form of heavy metals in soils is an important consideration in determining the hazard to human health and the environment. Some chemical forms of some heavy metals are very toxic.

3.3.1 Theoretical Basis for Soil Stabilization

Stabilization of hazardous wastes was developed as a treatment alternative to conventional solidification processes. Common stabilization compounds include phosphates, sulfates, hydroxides, and carbonates. The theoretical basis for metals treatment using a stabilization approach can be explained by studying the solubility of the metals of concern as a function of pH.

Figure 3-1 shows the solubilities of various lead species versus pH, for a system containing sulfate, phosphate, carbonate, and hydroxide ions. At low values of pH, free lead ion and cationic hydroxide complexes are the predominant soluble species. In the mid-pH range (6–9), the solubility of lead reaches a minimum. At high pH (pH > 11), the solubilities of the tri- and tetrahydroxy complexes [$Pb(OH)_3^-$ and $Pb(OH)_4^{-2}$] govern the soluble lead concentration. Under both low-pH conditions (pH<4) and high-pH conditions (pH>11), lead may be soluble at environmentally significant concentrations.

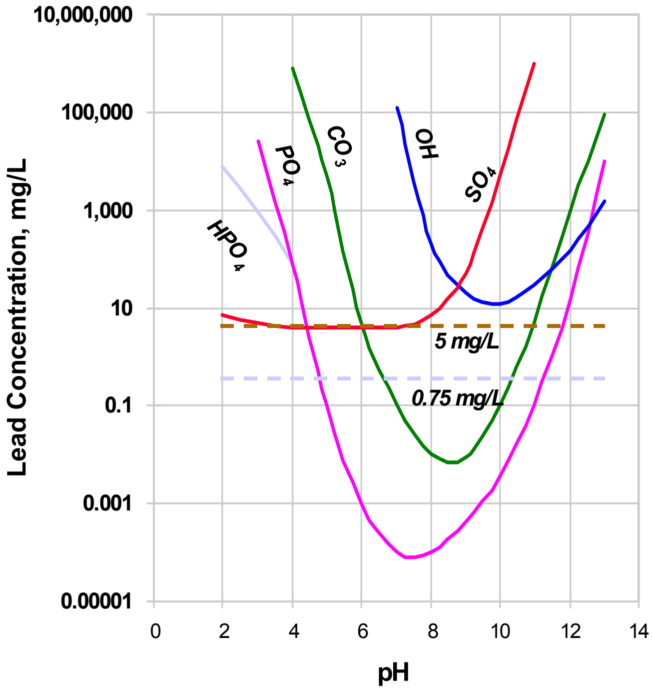

Figure 3-1. Solubility of Various Lead Compounds as a Function of pH

In regard to Figure 3-1, the concentrations associated with the horizontal dotted lines correspond to the current threshold toxicity characteristic concentration for lead (5.0 mg/L) and the universal treatment standard (UTS) for lead. Clearly, wastes treated with phosphate, and possibly carbonate and sulfate, can meet both of these criteria, although lead carbonates tend to form over long periods of time. The performance of either treatment system can be enhanced by including a buffering compound to maintain the pH of the treated waste in the range of 6 to 10. A buffering compound reduces the leachability of the lead immediately and also increases the waste's resistance to attacks by acids. For example, waste or soils buffered with as little as 1% magnesium oxide can theoretically resist leaching by acid rain for more than 1,000 years. This assumes an acid rain pH of 5, forty inches of rain per year, a waste depth of 10 feet, and a waste porosity of 30%.

Recent studies conducted by Ma, et al., funded by USEPA, have shown phosphate amendment to be a preferred method of stabilizing lead-impacted wastes. The results of leaching tests, electron microscopy, and various other investigations support this conclusion. Stabilization of wastes with the buffered phosphate system has been demonstrated to result in effective long-term treatment. USEPA's Multiple Extraction Procedure (MEP) has been used to test the long-term stability of treated wastes. The MEP, according to USEPA scientists, was designed to simulate 1,000 years of leaching with acid rain. It consists of an initial TCLP, with the leached solids being subjected to nine successive SPLPs. The TCLP lead in the untreated material was 50 mg/L, and the TCLP cadmium was initially 6 mg/L. Clearly, the leachability of the treated waste decreased with time.

Barring some environmental incident in which strong acid or alkali spills onto the treated material, future dissolution is highly unlikely. Furthermore, there is ample evidence that very stable lead phosphate compounds, specifically from the pyromorphite mineral group, form over time from the initial reaction products, such as amorphous lead phosphate and lead orthophosphate. Nriagu established the theoretical basis for this statement in his classic 1974 work.

3.3.2 Reducing Solubility through Soil Stabilization

Technologies are evaluated using only the Toxicity Characteristic Leaching Procedure (TCLP) or its predecessor, the EP toxicity test. The TCLP is designed to mimic conditions over an extended period in an actively decomposing municipal landfill, since the high-acid concentrations that can assault a waste over years are often not present immediately after disposal. The results of these tests are compared with the RCRA standards for characteristically hazardous material. When USEPA developed the Synthetic Precipitation Leaching Procedure (SPLP) and the Multiple Extraction Procedure (MEP), some regulatory bodies incorporated these tests as part of their evaluation regimen. The SPLP is designed to simulate 100 years of leaching with a worst-case acid rain containing nitric and sulfuric acids. The MEP, which consists of a TCLP followed by nine SPLPs, is designed to simulate 1,000 years of leaching. Many of those active in the remediation industry have felt that these tests, along with the TCLP, can more accurately predict immediate and long-term leaching behavior.

It is important to note that the TCLP solution contains about 1,000 times more acidity than the SPLP solution. Even though nitric and sulfuric acids used in the SPLP are "stronger" acids than acetic acid (the TCLP acid), strength refers only to the degree to which the acids are ionized. In a leaching test, the SPLP solution can be neutralized with milligram levels of alkalinity, whereas it takes several grams of alkalinity to neutralize the TCLP solution. So, even though the TCLP has flaws, it is a very rigorous test.

Sample quantities of soils should be obtained and tested at the bench scale to establish the proper mixing and mass of amendment required to stabilize the sample to pass previously described test(s). Results from these tests are transferred to the field scale, where climatic variables and heterogeneities of the soil are added to a field-scale test. Again, performance is based on the previously identified testing procedures.

Since the introduction of the TCLP, a variety of methods for stabilizing hazardous wastes have been commercially available. Some approaches simply use manipulation of the pH of the waste, so that the final pH in the TCLP will correspond to the minimum solubility conditions of the waste. Many solidification methods currently used for treating heavy metals, especially lead, involve mixing a high-pH, lime-based stabilization or solidification agent, such as Portland cement, cement kiln dust (CKD), or lime kiln dust (LKD) with the waste.

During the TCLP, the lime added to the waste neutralizes the TCLP's acidic leaching solution, and the resulting pH limits leaching of lead in the test. However, this added lime could produce leachate having rather high pH (11–12) when the waste is contacted with groundwater, precipitation, or surface water. Under such conditions, amphoteric metals, such as lead, can reach unacceptable concentrations in leachate, whether in laboratory water leaching tests or in the environment. Therefore, lime-based treatments may enable wastes to pass the regulatory TCLP requirement but can create severe environmental problems under actual leaching conditions.

Table 3-2 presents actual leaching data that demonstrate the increased leachability of lead from a waste treated with three different solidification/stabilization approaches. The benefit of using a TCLP and a SPLP to detect potential problems related to inappropriate treatments is apparent. All three treatments (buffered phosphate, lime, and Portland cement) are capable of rendering the waste nonhazardous with respect to the TCLP lead leaching. However, solidification with either lime or Portland cement (a lime-based material) substantially increases the leaching of lead in the SPLP. In other words, the alkaline materials used in the solidification process enable the waste to pass the TCLP but can actually create problems in a disposal situation where high concentrations of acid do not exist. Examples might be an industrial monofill, a municipal landfill with freshly disposed waste where the decomposition process has yet to start, or a natural setting such as a shooting range berm. It is possible that the high-pH levels being observed in several Subtitle D landfills (and concomitant aggravated leaching of metals) could have been caused by the practice of solidifying wastes with alkaline materials in order to pass the TCLP.

	TCLP (Acid)		TCLP Threshold (mg/L)	SPLP (Water)	
	Lead (mg/L)	Final pH		Lead (mg/L)	Final pH
Untreated	600	6.0	5.0	<0.003	8.2
Lime (Calcium Hydroxide) (% by weight)					
+5%	76	6.5	5.0	290	12.2
+10%	0.2	8.6	5.0	540	12.5
+15%	6.2	10.4	5.0	510	12.5
Portland Cement (% by weight)					
+5%	450	5.3	5.0	19	11.5
+15%	< 0.2	10.4	5.0	11	11.9
+25%	1.2	11.6	5.0	12	11.9
Buffered Phosphate (% by weight)					
+4%	2.4	5.8	5.0	<0.003	10.6
+6%	0.4	5.5	5.0	<0.003	10.3
+8%	< 0.2	5.6	5.0	<0.003	8.5
Note: All samples were crushed to pass a 9.5-mm sieve per the Method 1311 Toxicity Characteristic Leaching Procedure, 40 CFR, Part 261, Appendix II					

Table 3-2. Treatment of a TCLP-Hazardous Metal Processing Waste

3.3.3 Reducing Lead Bioavailability through Soil Stabilization

There are several approaches that can be used to immobilize lead in soil. In general, lead can be immobilized or made less bioavailable by reducing the solubility of Pb-bearing minerals through a change in pH, converting lead to a chemically more stable form, or solidification of the soil matrix. However, converting lead to a chemically more stable form appears to be the most effective way to reduce mobility and bioavailability in lead-contaminated soils. To accomplish this, lead-contaminated soil is treated with various types of amendments. These amendments are applied to the soil in a variety of ways, including wet or dry forms and *in situ* or *ex situ* applications. The reduction in solubility following the addition of amendments reduces the potential for leaching to groundwater and may result in a lower bioavailability.

The effectiveness of the immobilization process has generally been ascertained by two methods: sequential extraction and the physiologically based extraction test (PBET). The most common sequential extraction procedure assesses the exchangeable lead, lead carbonates, lead associated with Fe and Mn oxides, Pb associated with organic matter and sulfides, and residual lead (Rapin, et al., 1986). A shift in lead distribution toward the residual fraction is used to indicate immobilization after treatment with phosphates. The lead extracted in the PBET is indicative of that which is available for uptake through the gastrointestinal system (Ruby, et al., 1996).

Research studies have been conducted to investigate the effectiveness of adding amendments to stabilize lead-contaminated soil. Some of these research studies are summarized below.

- Preliminary results of a swine soil dosing study at the University of Missouri (Drs. Stan Casteel and Robert Blanchar, personal communications) and a Sprague-Dawley rat dosing study at the U.S. Department of Agriculture–Agricultural Research Service (USDA–ARS) (Dr. Sally Brown and Rufus Chaney, personal communications) indicate a significant reduction in soil Pb bioavailability as a result of adding phosphorus alone or in combination with FeOOH to lead-contaminated soil (total soil-Pb about 4000 mg/kg).

- Studies by the Remediation Technologies Development Forum's (RTDF) IINEERT Soil-Metals Action Team have shown that commercially available stabilization agents have been effective in reducing bioavailability by as much as 83% in lead-impacted soil.

- Soil-borne lead was converted to pyromorphite by evaluating the reaction of lead-contaminated soil with hydroxyapatite during sequential extraction (Ryan, et al., 2001). The results of the experiments indicated that the addition of hydroxyapatite caused a decrease in each of the first four (i.e., most soluble) fractions of sequential extractable lead and a 35% increase in recalcitrant extraction residue. A 240-day incubation at field moist conditions resulted in further increase in the recalcitrant extraction residue fraction to 45%.

- The transformation of soil-borne lead to pyromorphite by soil treatment with phosphoric acid on a smelter-contaminated urban residential soil was investigated (Yang, et al., 2001). The results indicated that increasing the amount of phosphoric acid and elevating the temperature significantly decreased bioaccessble lead by 60% using the PBET method.

- In a study by Sauve, et al. (1998), the solubility of lead phosphate in water and soil suspensions was addressed. The study also investigated the stability of lead phosphate mixed with soil to determine the pH-dependent solubility of lead in the presence of excess phosphate in soils. The study concluded that phosphate amendments and lime are effective ways to reduce the solubility, mobility, and bioavailability of lead, with the optimum pH to reduce solubility in the range of 5.5 to 6.5.

- Laperche, et al. (1997) investigated the effect of apatite amendments, specifically synthetic hydroxyapatite, on plant uptake from lead-contaminated soil. The results of the study, along with other previous studies, indicated that addition of phosphate to lead-contaminated soil could immobilize lead as an identifiable stable form such as pyromorphite. Also, the study showed that by amending synthetic hydroxyapatite and phosphate rock to lead-contaminated soil, bioavailability (as indicated by plant uptake) can be reduced.

- Lead-contaminated soil was amended with triple super phosphate (TSP), rock phosphate, or manganese oxide (cryptomelane) (Ganga, et al., 2000). The addition of a combination of a phosphate source and the Mn oxide resulted in lower bioavailability (23%–67% reduction) as measured with the PBET test than with either amendment alone (14%–41% reduction).

3.4 Chemical Extraction

Chemical treatment is a proven technology when combined with a physical treatment/soil-washing approach. It involves introducing a leachant (for lead, this is generally a strong acid) into the water used in a physical separation or into a soil-washing process to promote the dissolution of residual metals into solution after particulate metal removal. While weak acid (acetic) has been used in the field, the nuisance odors and relative low strength limit its efficiency. As such, hydrochloric acid is most often used for chemical leaching. Acid addition aims to solubilize metals from the soil by changing the pH. Adding acid lowers the pH and increases the supply of H^+ ions. The H^+ ions generated are consumed in a multitude of reactions that increase soluble metal concentrations.

Chemical treatment is a continuous process with the following steps:
- Bringing acid and soil into contact in a leach tank
- Separating the leached soil from spent leachant
- Regenerating the spent leachant by precipitating the dissolved metals

Once in solution, the dissolved metals are recovered through a co-precipitation step involving the addition of a polymer to adjust pH. The settled soil fines go through a series of rinse and dewatering steps for reuse on the site, while the settled precipitants are dewatered for subsequent recycling with the recovered particulate metals.

Equipment additions to the base soil-washing plant include acid storage tanks, dispensing pumps, and pH meters, as well as systems for recovering metals from solution and dewatering/ discharging recovered metals (precipitant).

Two important range soil material characteristics for designing an appropriate separation/ leaching scheme are the particle sizes of the material and the metals distribution by fraction. Other than the mechanical aspects of treatment, clay soils tend to bind metals better than sandy soils and tend to be more difficult to treat. These limitations are discussed in more detail in Section 5.5.

3.5 Asphalt Emulsion Batching–Encapsulation

Tall oil pitch and asphalt-based emulsions have been used extensively in the commercial construction industry to stabilize soils for dust control, thereby minimizing their mechanical migration through wind or water erosion. These same emulsions have been modified (and the modifications patented) to encapsulate heavy metals (such as lead, uranium, arsenic, and chromium), rendering them resistant to leaching to groundwater and creating a material that reduces infiltration and is resistant to wind and water erosive forces. Chemical theory indicates the technology would also work on heavy organics (PCBs, DDT, etc.).

In July 2000, USEPA issued a determination that use of encapsulation technologies qualifies as recycling for RCRA characteristic wastes, in that permanent chemical bonding is achieved in a commercially useable end product. Treated soils exhibit increased soil strength and can be used as an asphalt base material. The technology is especially applicable for military ranges (lead and DU contamination), military base reuse sites (where treated soils can be used to construct new roads), and other applications. The emulsions can be mixed into the soil and/or applied topically.

The objective of the technology is to provide permanent encapsulation of contaminated soils, where the resultant treated soil exhibits reduced leachability of the contaminant, reduced permeability of the soil surface, and increased soil strength to withstand wind and water erosion. In most cases, the end product can be used as a nonhazardous construction material, road base, or structural fills. On military firing ranges, the soil can be topically treated or, in the absence of UXO, mixed and compacted. Resultant compacted treated soils typically exhibit high strength and low permeability characteristics.

The objective of site-specific demonstration testing would be to refine emulsion designs for specific application sites, evaluate and compare application methods, and implement rigorous postapplication monitoring to evaluate key performance data. Proposed testing would also evaluate the technology's efficacy on residual explosives in soil.

This patented technology includes improvements over other stabilization technologies. Most previous stabilization technologies do not exhibit "permanent" treatment and are subject to loss of effectiveness under changing physical or chemical (pH) conditions. Additionally, most stabilization technologies do not work well on a range of inorganic and organic contaminants.

The use of specially modified organic emulsions has proven effective as permanent treatment on lead-contaminated soils in full-scale implementation and on depleted uranium, arsenic, and chromium in laboratory treatability tests. The technology has been used to improve road foundation soils at Ft. Hunter Liggett and to treat lead-affected soils for a Caltrans highway project in Richmond, Calif. Once soil-specific emulsion design testing is completed, implementation of this technology in the field can be done with normal road construction equipment and crews.

Laboratory testing for the U.S. Army indicates that the technology is extremely effective at stabilizing depleted uranium from munitions. Full-scale field testing is proposed to compare field application techniques and evaluate its performance in the presence of possible unexploded ordnance. Additional testing also indicates a high potential for success in stabilizing residual uranium daughter products (cesium) from atomic weapons testing.

3.6 Phytoextraction and Stabilization Approaches

While phytoextraction is proven to remove lead from soils, the relatively high levels of lead at SAFRs and the time required for effective phytoextraction render this technique impractical as a range remediation tool. However, other phytoremediation techniques such as phytostabilization and use of constructed wetlands can complement the overall remedial approach and prevent migration of lead particulates through prevention of erosion and storm water management, respectively.

In-place inactivation has been recently coined to describe this process of chemically and physically inactivating contaminants, both in soil and other materials found at the earth's surface. Other names for this strategy include *phytostabilization*, *agronomic stabilization*, and *phytorestoration*. In this process, no actual reduction in pollutant concentration occurs. The risk reduction is provided by chemical and physical processes that allow the soil to remain in place. Chemicals and materials that appear to be most promising for in-place inactivation include phosphates, mineral fertilizers, iron oxyhydroxides, other minerals, biosolids, and limestone. Conversion of Pb to less toxic forms has been demonstrated in soils amended with safe additives using common agricultural techniques.

To complement the use of soil amendments, a rich plant growth in treated areas will help hold soil in place by preventing erosion, reducing rain impact, and providing an effective barrier against direct contact with soil. In some cases, plant roots may absorb contaminants to further prevent off-site migration or leaching. Incorporating soil amendments and growing plants using existing agronomic techniques are more natural ways of restoring the ecology of soil in comparison to many other remediation technologies. Importantly, this agriculturally based technique should be less likely to impair the soil's potential for sustaining plant growth after treatment and be relatively environmentally benign when compared to many conventional remediation practices

Please refer to www.itrcweb.org for technical and regulatory requirements for phytotechnologies.

4.0 REGULATORY REQUIREMENTS, BARRIERS, AND FLEXIBILITIES

Remediation of shooting ranges is an increasing concern for both owners/operators of closed ranges and environmental regulators. It has become evident that lead management practices are inconsistent, and owners/operators of closed ranges are often unaware of the appropriate path forward. While understanding the regulatory flexibilities is imperative to range cleanup, it is also important to understand the regulatory barriers. Of particular note is the need to understand both the state and federal regulatory requirements. The sections below outline the regulatory requirements that should be considered during the cleanup of small arms firing ranges.

4.1 Classification of Spent Ammunition

A key issue to be resolved is whether spent ammunition is classified as a solid waste or a contaminant. Partially for this reason, no state or federal laws or regulations exist that set specific environmental standards for operation of firing ranges. For instance, the Clean Air Act under Section 112(b) 3 (7) excludes elemental lead as a hazardous air pollutant. Furthermore, under CERCLA, releases of lead particles with a mean diameter of over 100 microns are exempted from being reported. If the site is not listed on the National Priorities List under Superfund, state equivalents of the Clean Water Act or the Solid Waste Disposal Act are the most likely vehicles for development of comprehensive environmental standards at shooting ranges.

USEPA has defined “scrap metal” as “bits and pieces of metal parts or pieces that may be combined together with bolt or soldering, which when worn can be recycled” (40 C.F.R. 261.1). Since lead shot is a product made of recyclable metal, it falls within the definition of scrap metal. In accordance with 40 CFR 261.6(a)(3)(ii), scrap metal is a solid waste but is exempt from the regulatory requirements of RCRA Subpart C. Additionally, as outlined in the Federal Register (62 Federal Register 25998, May 12, 1997), processed scrap metal is exempted from RCRA regulation (i.e., is not a RCRA solid waste) when it is being recycled (40 CFR 261.4(a)(13). Therefore, as long as the selected remediation technology (e.g., soil washing) meets the definition of processed scrap metal, the technology is exempt from regulation under RCRA.

4.2 Federal Regulations and Guidance

The management of soil from shooting ranges is evolving and likely will continue to do so. The current management of active shooting ranges is being shaped primarily by two lawsuits: *Connecticut Coastal Fisherman’s Assoc. v. Remington Arms Co*., 989 F.2d 1305 (2d Cir.1993); and *Long Island Soundkeeper Fund v. New York Athletic Club,* 1996 WL 131863 (S.D.N.Y.). USEPA published the RCRA Subtitle C Military Munitions Rule (MMR) in the Federal Register (62 Fed Reg. 6621). USEPA has also published a guidance document entitled *Best Management Practices for Lead at Outdoor Shooting Ranges*. The subsequent resolution of these suits and their associated range cleanups prompted USEPA to develop its guidance document. Part of the impetus to develop this guidance was the realization that, because of its relative high volume and

low risk, the management of shooting range soil may benefit from approaches that differed from those typically used at normally encountered hazardous waste-type facilities.
The management of closed military ranges is being shaped by the RCRA Subtitle C Military Munitions Rule (MMR). It was then adopted in September 1998 (40 CFR 266 Subpart M). However, the MMR is incomplete in that a large section, the "Range Rule," was never completed. USEPA is moving forward to complete that section, but it is unknown when it will be finalized.

Though originally intended to apply to federal facilities, USEPA has taken the position that the MMR also applies to nonmilitary ranges. The MMR excludes munitions used for their intended purposes from the definition of a solid waste and, therefore, excludes munitions from regulation as a hazardous waste. This exclusion applies to training, research, development, recovery, collection, and on-range destruction of unexploded ordnance (UXO). The Military Munitions Rule considers range management to be a necessary part of the safe use of munitions for their intended purpose. The exclusion for range clearance applies to the separation of lead and bullets from soil and the redeposition of soil on the range.

If spent lead at a shooting range is abandoned (or is determined to be abandoned), it then becomes solid waste. If the solid waste accumulates on ground surface and, therefore, causes lead leaching, it may be considered a hazardous waste. At that point, the lead contamination could be subject to RCRA Subtitle C.

States adopting this rule may set more stringent requirements for determining when military munitions are solid waste; or using this rule as a precedent, state agencies may elect to implement a regulatory scheme that is protective without requiring a full RCRA permit. The rule does not exempt ranges from Clean Water Act requirements.

4.3 State Regulations and Guidance

Storm water collected and conveyed in ditches or pipes prior to discharge is potentially subject to permit requirements. Some shooting ranges may operate without discernable conveyances; however, contaminated leachate from these ranges could be considered a nonpoint source as it moves laterally into surface waters. Some states, like Florida, are recommending that small arms firing ranges develop and implement a site-specific best management practice (BMP) instead of developing rules for small arms firing ranges. The main goal of the BMP is to have a good storm water management plan that includes routine maintenance to minimize off-site migration of lead and other contaminants. The key components include

- monitoring and adjusting pH in soils,
- controlling and containing lead bullet fragments,
- controlling storm water runoff,
- bullet containment devices,
- removing and recycling lead,
- using alternate ammunition (lead shot alternatives),
- minimizing shooting area (reducing shotfall zone),
- documenting activities and keeping records, and

- determining the frequency of lead removal and pH adjustment in soils.

While the consensus to date has been that shooting ranges should not be subject to hazardous waste regulations, some states have authority to regulate any discharge from a facility with the potential to contaminate groundwater. For example, Florida has unique geology and relies heavily upon groundwater as a source of drinking water, which needs to be considered when evaluating potential contamination from shooting ranges. This consideration is in addition to the widely accepted guideline that lead shot and bullets should not be deposited in surface water or wetlands. A public shooting range in Naperville, Illinois became the first site for which a state agency issued a NPDES permit for a shooting range discharging to a wetland.

In Florida, an "installation" is defined as "any structure, equipment, facility, or appurtenances thereto, or operation which may emit air or water contaminants in quantities prohibited by the Department of Environmental Protection [DEP]." Specific types of "installations" such as landfills and wastewater treatment plants may be further defined as "stationary installations." State environmental agencies may, therefore, claim authority to require permits prior to construction of new shooting ranges based upon several issues:

- Shooting ranges are both "installations" and "stationary installations."
- Shooting ranges are known to discharge pollutants into the environment.
- Several shooting ranges in Florida have violated state groundwater and surface water protection requirements.
- Several shooting ranges have degraded wetlands and caused harm to wildlife.

Other states have similar antidegradation policies and laws. In general terms, these laws prohibit the discharge of contaminants into the environment without permit(s) from the state environmental agency. This policy applies to releases to the soil, groundwater, surface water, and air. State and local agencies may have permitting requirements or remedial performance standards in addition to, or more stringent than, federal requirements (e.g., strict cleanup standards, transportation permits, permits for working near wetlands, etc.).

4.4 Remediation/Future Use Issues

Some state agencies are informally collecting information on the location of outdoor shooting ranges. Owners of closed ranges should be required to notify state agencies if they become aware of soils on site that are present in amounts that pose a risk based on current or reasonably anticipated future land use or if exceedances of groundwater quality standards are detected.

For closed shooting ranges, policy should be developed in the following areas:

- How will the agency locate operating and closed shooting ranges?
- Will the state require all closed ranges to conduct site cleanups? If not, will they be required to do so under new ownership or land use?
- What mechanism will be used to require cleanups?
- Will self-certification be accepted? How will it be verified?
- What state agency program will have primary responsibility to oversee cleanups?

"The City of Tampa and the Hillsborough County School Board worked with the [FDEP] District [office] to remediate a pistol range site in order to build a new school. Because of liability concerns, the Board needed assurance that the site was safe for residential use before they would accept the property. However, at the same time, the owner of a private shotgun range in Hillsborough County declared his property 'clean' by using a limited biased sampling plan and sold the property for residential development. The owner's consultant took 20 soil samples from 1 to 2 feet below land surface throughout the range, rather than 0 to 2 feet, thus excluding the most suspect soils from his samples. Conversations with management at [the land developer] confirmed that they were aware that the property had been used as a range and that no soils were removed prior to development. Management said that a large amount of fill was brought in to raise the grade of the residential lots. However, these lots will be sold to unsuspecting homeowners who will not know that their property may be lead-contaminated. There is no assurance that contaminated soil will not be excavated, as for a swimming pool installation, and then disposed elsewhere on the surface."

This scenario, in which "capping" was the selected remedial alternative, presents an example of why state environmental regulators need to become involved early in the process and why future land use considerations are important factors when crafting appropriate and enforceable deed restrictions.

4.5 Lead Recycling

During remediation activities, recovery of bullets and bullet fragments from firing range sands or soils via physical treatment constitutes "reclamation" per 40 CFR 261.1(c)(4). Metal concentrates reclaimed from firing range berms via size classification and density concentration contain more than 50% lead on a dry weight basis. The other metals included in the concentrate are predominantly copper and antimony. The concentrate reclaimed from the firing range material is "scrap metal" per 40 CFR 261.1(c)(6).

However, scrap metal 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 specified in paragraphs (b) and (c) of 40 CFR 261.6. Therefore, the scrap metal reclaimed from the firing range sand, or soil, does not need to be regulated or manifested as a hazardous waste during generation or transport to a smelter for recycling.

When scrap metals reclaimed from remediation activities are recycled using a smelter, the generator is paid for the value of the reclaimed metals minus any smelter handling fees. All material recovered should be shipped under bills of lading for recycling. Some of the recycling processes automatically bag all recovered metals in DOT-compliant super sacks, which are palletized for ease of handling and shipment.

4.6 Live Rounds/UXO

A potential hazard at Department of Defense small arms firing ranges is "live rounds," referred to as unexploded ordinance, or UXO, from nearby previously conducted large arms range activities. Additionally, all small arms firing ranges may contain live small arms rounds. Quite often these items are overlooked in treatability testing or site characterization. Both are addressed in more detail below.

UXO

UXO presents significant safety hazards in the form of unintended or spontaneous detonation, as well as a potential contaminant source through the dispersion of propellants and explosives through cracked casings and/or low order detonation. These issues are addressed by the ITRC UXO Team and their related guidance documents.

The intent of this section is to emphasize that while the focus of this document is dealing with small arms firing ranges, experience has shown that unexpected UXO is occasionally present even if there are no historic records indicating large arms use or storage at the site. If physical evidence or historical records indicate the presence of UXO, an appropriate response should be conducted by an explosives or munitions response specialist prior to conducting any required intrusive activities at a closed range. If UXO is present, a second sweep/clearance should be performed in the feed pile just prior to treatment. The process plant operators should also be trained in UXO recognition, with appropriate shutdown and notification procedures in place in the unlikely event UXO makes its way into the treatment plant.

Small Arms Rounds

Experience has also shown that hundreds of pounds of live small arms rounds, along with "duds," end up in range soil as they are recovered during range soil processing operations. The wet screening and water-based density separation process (soil washing) is well suited to deal with these issues, as all operations are under water in steel tanks, and the density separation step isolates the live rounds for recovery and subsequent destruction as part of the process.

Once removed and containerized, live rounds are typically classified as ORM-D materials for shipping to a DoD-approved facility for subsequent destruction. For bases with an active Explosives Ordnance Disposal (EOD) group, the ORM-D materials could be transferred to the base EOD group for ultimate disposition.

4.7 Soil Recycling

Under current regulations, waste that is recycled and "used in a manner constituting disposal" is exempt from RCRA regulation if the resulting product is produced for the general public's use, contains recyclable materials that have undergone a chemical reaction so as to become inseparable by physical means, and meets Land Disposal Restriction (LDR) treatment standards (see 40 CFR 266.20 (b)).

USEPA has recognized a process utilizing asphaltic and/or plant-based organic emulsions, modified with proprietary and patented chemical formulations, to enhance the structural characteristics of contaminated soil and to chemically fixate hydrocarbon and metal contaminants found therein. The resulting product meets structural specifications for commercial granular and asphaltic road base materials.

This recycling process for RCRA waste satisfies the criteria set forth in 40 CFR 266.20 (b):

- The resulting product meets engineering and regulatory standards for commercial roadway construction materials. The process was recently used on a California State Highway project involving "Cal-Only" waste material. Thus, it is produced for public use as a construction product.
- The resulting product uses the contaminated soil as a necessary and integral part of the finished structural material. The process produces chemical fixation or stabilization of the waste material. Further, waste-derived cement and asphalt products were deemed to have satisfied the "chemical reaction" requirement when the final rule was issued in 1985 (see, Federal Register, Vol. 50, No. 3, p. 646).

To be allowed under 40 CFR 266.20(b), the resulting product must satisfy the LDR treatment standards pursuant to the appropriate test procedure. The resulting product has been proven to pass these tests.

4.8 Transporting or Relocating Range Soil for Reuse as a Backstop on Range Property

At some ranges, it may be possible and desirable to reuse the soil from the backstop of a range that is being closed to construct a new berm or rebuild an existing berm located in another area of the same property or facility. It is USEPA's position that ranges that reclaim and recycle lead bullets or lead shot may place the soil that is generated during the reclamation process back onto an active range on the same property or facility or a property adjacent to and under the same ownership as the property where the soils originated, without testing the soil for hazardous waste characteristics. In many situations, range soil has proven to be high volume but relatively low risk.

Consistent with this approach, range soil that has been processed to reclaim lead for recycling is considered a construction material if it is used to construct or rebuild a backstop on the same site. Defining the "site" in such a manner to allow the soil to be reused to construct another shooting range component on the same range property or on an adjacent range property, under the same ownership and control as the property where the material originated, is an option that deserves consideration. Range soil includes soil from a former backstop or from other parts of the range. As a construction material, range soil after reclamation is not considered as either a solid or hazardous waste.

If there is a need for backstop construction material elsewhere on the property at which a range is being closed, then the option of reusing the range soils after reclamation should be considered. The potential environmental benefits of this approach include reusing a "manmade structure," i.e., berm, in a manner that is consistent with reusing other construction material; avoiding use of new soil on a new or existing backstop, thus preventing the new soil's ultimate future contamination from small arms ammunition; consolidating several berms containing contaminated material into fewer berms; and avoiding costs associated with testing and disposing of the soils from the former backstop as hazardous waste. Reusing this material is also consistent with the trend to look for creative ways to recycle and reuse material rather than disposing of it. The cost of the reclamation process is a function of the time, labor, equipment used to segregate the lead bullet fragments or shot from the former backstop, and transportation to a recycling facility/smelter. These costs are offset to some extent (depending on the amount of lead that has accumulated in the backstop and the efficiency of the reclamation process) by the price received from the scrap metal recycler/smelter for the recovered lead. In addition, there is a cost savings related to the construction material for the new or rebuilt backstop.

It is important to note that lead reclamation and recycling is required for the soil to be considered a construction material. If lead reclamation is not conducted prior to moving the backstop, then pursuant to RCRA, the movement of the backstop may be considered illegal disposal of hazardous waste.

It has been suggested that range soil from a former backstop may also be reused, following lead reclamation, for constructing or rebuilding a backstop at a location that is not on the range property. The same environmental benefits mentioned above could be realized, but extra oversight may be needed. Since individual states may not permit this action, or may impose additional requirements for transportation, documentation, and approvals, state regulators should be consulted prior to transporting range soils to a property that is not the same as or adjacent to and under the same ownership as the property where the soils originated.

Finally, once range soils have been removed and relocated for use in a backstop at another range, assessment of the area under and surrounding the former backstop should be conducted as part of the site characterization as described elsewhere in this document.

4.9 Disposal of Range Soil

Disposal of soil containing a hazardous waste is addressed by USEPA's "contained-in" policy. Under this policy, soil can be classified as either hazardous (listed or characteristic) or nonhazardous, based on key parameters. For range soils, the relevant parameter is toxicity. The soil that is removed from a closed range for treatment or disposal may be considered to contain hazardous waste and classified as "characteristically hazardous" if it exhibits the characteristics of toxicity.

However, the soil can be considered to no longer contain a hazardous waste through removal of the live rounds and particulate lead, with residual stabilization, if required, to meet the regulatory TCLP level of 5 mg/l. Once the soil is viewed as not containing lead, the soil may be able to be disposed of at a Subtitle D (nonhazardous) facility. Any applicable land disposal restrictions should be consulted. It should be noted that individual states may not utilize the contained-in policy (and, thus, these soils would be regulated under RCRA) or may have additional, more stringent disposal requirements.

5.0 TECHNOLOGIES AND TECHNICAL CONCERNS

For DoD, small arms firing ranges may present significant environmental concerns because the soil on a closed range contains lead. The soils on a closed range may exceed hazardous waste criteria and require either treatment or removal. The approach outlined herein uses soil washing as the first step to remove particulate metals. In many documented cases, this step alone has been sufficient to render the soils nontoxic and suitable for reuse. If treated soils do not meet reuse criteria after soil washing, then additional treatment can be selectively performed on only those fractions that caused the soil matrix to fail.

5.1 Treatability Study

A treatability study using representative site soils is imperative to determine appropriate treatment methods at any site, as well as to predict actual scaleup and field performance of the selected approach. Experience has shown that firing range soils vary significantly from site to site and even at different locations within a given site. Variations in soil that affect treatment procedures include grain-size distribution, clay content, physical characteristics, mineralogy, aggregate hardness, soil pH, and the form and distribution of contaminants.

Samples collected for treatability testing must be representative of the anticipated soils for treatment. A compositing approach as described in Appendix B is useful for range floors and lateral berms where the depth of contaminants is relatively shallow. For the primary berm, face trenching is often a preferred approach, as it allows for visual inspection of the berm cross section to help determine if additional soil was added or if the berm face was “turned over” as part of maintenance and, thus, indicates the potential depth for ultimate remediation.

In the case of test trenches, grab samples should be collected from the trench walls and floor at different depth intervals through the cross section, allowing equal contribution from each grab sample collected. These grab samples are then composited in a cement mixer, and a representative sample is drawn for subsequent treatability testing. A five-gallon sample is typically the minimum size required for testing, but one should confirm with one’s proposed treatability lab prior to collecting samples.

The initial step of the treatability study should include a step-wise evaluation of density separation for particulate metals consisting of

- grain-size analysis/containment by fraction,
- contaminant removal by size segregation and gravimetric techniques,
- oversize fragment removal by size segregation and screening, and
- post-treatment and TCLP metal results for each individual size fraction.

The treatability study will focus first on material characterization of the sample, followed by optimizing treatment of specific fractions using physical treatment methods. Recoverable quantities of metals will be estimated in the treatability study to quantify the amount requiring recycling.

Density separation/soil-washing techniques evaluated during this treatability study should include the following:
- deagglomeration steps to separate sod/vegetative material from soil fractions,
- physical treatment employing a wet screen for particulate partitioning, and
- density treatment to further separate geologic material from same-sized metal particulates.

Results of the treatability study will reveal the appropriate treatment approach for implementing the full-scale remediation. In the event site cleanup goals are not met after initial particulate lead removal, fractions failing cleanup goals should undergo further treatment to supplement the initial soil-washing process. Further treatment may include
- stabilization,
- chemical treatment,
- emulsion stabilization of both organic and residual metal compounds, or
- phytoremediation.

Only the soil fraction(s) failing reuse criteria need to undergo these additional treatment steps. This approach yields cost savings through volume reduction, as soil washing generally partitions sorbed organic and metal contaminants into the finer soil fractions while rendering sand and coarser fractions suitable for reuse after particulate removal. Results of the treatability study dictate the appropriate treatment approach for implementing the full-scale remediation. Treatment effectiveness and implementability are presented in the treatability study report. The report also includes the most appropriate means of handling the recovered metal. A sample scoping document for treatability testing is included as Appendix C.

5.2 Data Needs

For any remedy to be effective, accurate soil information must be available prior to process selection. Factors that influence performance include but are not limited to
- grain-size distribution,
- organic content (humates),
- contaminant form and distribution,
- clay content/ plasticity,
- mineralogy,
- soil pH,
- aggregate hardness,
- type and level of use of the range in question,
- past range use and maintenance records, and
- climatology records.

This information is best collected through a review of historical records and any existing soil characterization, supplemented by a treatability study and additional characterization as deemed necessary to fill data gaps.

5.3 Soil Washing

Soil washing is a source removal technology that physically separates particulate metals from the soil matrix and refines them such that they have a commercial salvage value. The system treats SAFR soils by removing spent bullets and bullet fragments from the soil through a physical solids-separation technology and then treating the remaining soil, if required, with the appropriate secondary treatment approach.

In addition to metal recovery, soil washing can segregate a soil fraction that is ideal for use as ballistic-grade sand in berm reconstruction. By using ballistic sand that is free of stones, sticks, and excessive fines, bullet fragmentation is eliminated, and simple sifting is sufficient for subsequent maintenance activities. For closed ranges, the treated soil is suitable for reuse, thereby eliminating the need to purchase replacement soil for site restoration.

5.3.1 Treatment Efficiency

The efficiency of the technology is measured by the average total lead concentration in the feed soil compared to the average total lead concentration of the treated soil stockpile. For example, if 21 tons of metal is recovered via physical treatment and 84%, or 17.64 tons, was determined to be lead, the balance of the metal recovered for recycling would typically consist of copper, zinc, and antimony. Again, assuming that approximately 3,600 tons of range soil was processed, dividing 17.64 tons of lead by the total amount of material processed (3,600 tons) results in the average percentage of particulate lead for the feed soil of .49%. On an mg/kg basis, .49% is equivalent to 4,900 mg/kg, thus the feed soil contained an average particulate total lead concentration of 4,900 mg/kg. Adding the particulate lead concentration (4,900 mg/kg) and the residual total lead concentration in the treated soil (assume 300 mg/kg) results in the feed soil containing an average total lead concentration of 5,200 mg/kg.

Physical treatment would have reduced total lead levels in the soil from an average of 5,200 mg/kg to an average of 300 mg/kg, a lead reduction efficiency of almost 95%. These numbers are typical for this type of treatment arrangement and were taken from actual case studies. This technology has also been successfully used in soils with feed soil levels as high as 40% lead.

5.3.2 Technology Acceptance

Acceptance of the soil-washing technology has been very positive. This positive response is related to key elements in the application of this technology, as seen by the regulatory community, the client, and the general public.

Heavy-metal complexing agents are commonly used to stabilize soil contaminated with lead. With this approach, the complexing agents do not reduce total lead concentrations, and the stabilized soil is often shipped to a landfill for indefinite storage although on-site reuse is acceptable with some stabilization technologies. The overall benefit of the stabilization approach is that the soil can be shipped to a nonhazardous landfill with lower tipping fees than a landfill designed to receive hazardous waste.

With soil washing, lead contamination at small arms firing ranges can be dramatically reduced using physical treatment only, without the use of other expensive and long-term treatment technology. Also, case study work by the Army Environmental Center has shown that continued firing into berms that have been chemically stabilized with certain chemical agents can actually worsen the lead mobility issues. This is not necessarily a stabilization agent problem but rather a design problem. (MFW-3)

Of particular interest to the Department of Defense is the effectiveness of the technology for remediating soils at small arms firing ranges. Soil washing offers site closure or reuse within a very short time frame, without long-term environmental monitoring. This approach has the added benefit of recycling all of the reclaimed particulate lead. Thus, the client also gains a proactive public image with respect to resource recycling.

5.3.3 Public Acceptance

During a technology demonstration at Fort Dix, N.J., the general public perceived soil washing positively. Physical treatment of small arms firing ranges is a very effective pollution prevention measure. The dramatic reduction in total lead concentrations with physical treatment using water only and recycling the lead reclaimed from the soil was instrumental in generating this positive public image. The technology demonstration illustrated that effective soil treatment can be performed without relying on stabilizing the contaminants and landfilling the soil.

In addition, at one site standard control measures were successfully used to avoid generating excessive noise at the work site. The work site was maintained in an orderly fashion from site mobilization through processing and demobilization. Demonstrating the minimal aesthetic impact of this process is critical in gaining public acceptance for on-site treatment of contaminated sites in the vicinity of residential areas or within the boundaries of military facilities.

The general public is concerned with the following issues:

- The clean portion of separated soil must be analyzed for residual contamination before it is used as clean material. Sites using soil washing should have on-site capability to test samples of treated soil before it is released as clean.
- Soil contaminated with both metals and organic compounds make formulating a single suitable washing solution difficult. Sequential washing using different wash formulations may be required. Soil-washing processes for soil contaminated with volatile organic compounds (VOCs) may require emission controls.
- Wash water containing inorganics may require treatment before it can be discharged, as it is usually not completely free of smaller inorganic particles.
- Measures should be taken to prevent wind-borne particulates if dry screening is a step in the process.

5.3.4 Full-Scale Soil-Washing Costs

Treatment of small arms firing ranges utilizing soil-washing technology fits a mining-type economic model based on mass production. The volume of soil is the driving force behind treatment costs on a per-ton basis. Typical of a mass production model, cost elements such as mobilization/demobilization, labor, and capital outlay decrease with increased quantity in a nonlinear fashion on a per-ton basis.

Small arms firing ranges are highly variable with respect to soil and contaminant characteristics. Treatment goals and the quantity of soil requiring treatment are highly variable as well. A number of variables impact treatment costs when considering this technology for full-scale implementation at small arms firing ranges:

- mass of soil to be processed
- cleanup standards
- soil characterization (grain-size distribution and chemistry, including contaminant by fraction analysis
- site assessment risks
- split- or single-operations site
- throughput rate required
- weather conditions/time of year to operate
- level of personal protection equipment (PPE) required
- availability and cost of utilities
- sampling and sample preparation

Although sand, silt, and clay are the predominant soil matrices used in berm construction, one type of treatment process cannot be universally applied to all small arms firing ranges. The ideal treatment plant approach is to utilize unit components predetermined by the bench-scale treatability study as required for insertion in the overall treatment process. The typical price range for pile-to-pile processing varies from \$30/ton to \$80/ton, based on site-specific conditions/ requirements, as outlined in Table 5-1.

Option	Cost	Long-Term Liability	Land Use Restrictions	Perception Factor
Soil Washing	**$$$**	**L**	**R**	**Excellent**
• **Asphalt Batch**	**$**	**L**	**R**	**Good**
• **Chemical Extraction**	**$$**	**L**	**R**	**Fair**
Construction Material	**$**	**LL**	**RR**	**Fair**
Hazardous Disposal	**$$$$$**	**LLLLL**	**RRRRR**	**Poor**
Nonhazardous Disposal	**$$**	**LLLL**	**RRRR**	**Fair**
• **Stabilization**	**$$**	**LLLL**	**RRRR**	**Good**
• **Solidification**	**$$**	**LLLL**	**RRRR**	**Poor**

Table 5-1. Comparison of Various Types of Metals Remediation Technologies

Using this technology, soils can be treated and replaced on site, while recovered metals can be recycled. Recovered metals can be shipped as recyclable materials under bills of lading. Thus, no hazardous wastes are generated or shipped as a result of this process.

Public acceptance of this technology is high because it meets regulatory requirements without landfilling any contaminated soils and it reclaims hazardous contaminants for recycling in the process. In addition, because contaminants are removed and not just shifted to a landfill, potential long-term risks to human health and the environment are eliminated. These advantages must be balanced against the need to smelt the lead, which results in the generation of air containing solids and water, which may contain contaminants. The demonstration has shown that this technology can be implemented with minimal environmental or aesthetic impact to the processing area.

5.3.5 Recommendations for Future Applications

Based on the results and implementation of the treatability study findings for the design of the soil-washing plant, it is strongly recommended that every soil-washing solicitation include a vendor-conducted, bench-scale treatability study for effective costing and plant design. The bench-scale treatability study represents an effective method for fully defining a remediation problem, associated treatment parameters, and plant design.

Establishing physical treatment operations within the confines of the small arms firing range is ideal. Locating the treatment plant in the range facilitates the timely excavation and haulage of soils destined for treatment, as well as the return and placement of the treated soil. When fieldwork is confined to one location, the project is more efficient and overall project costs are reduced.

5.4 Soil Stabilization

Prior to stabilizing soil, a bench-scale treatability study is typically performed to determine a dose rate and reagent mixture that successfully meets the performance standards. Representative samples of the waste material are obtained and characterized prior to trying potential technologies. The mix design includes the type of reagent to be used and the appropriate rate of addition. The treatability study should be formatted to address pertinent regulatory concerns and long-term liability issues.

Stabilization at firing ranges is performed either *in situ* or *ex situ*, often depending on the regulatory program under which the work is performed. *In situ* stabilization can be used to avoid regulatory approvals needed to treat hazardous waste by treating prior to the point of generation for the waste. In the case of soil, this is when the soil is excavated and "managed" or when it is moved from an area of concern (AoC).

In situ treatment can be performed in a variety of ways. Typical *in situ* methods include mixing with standard earth-moving equipment, such as a tracked excavator, a clam shell, or an end loader; mixing with agricultural equipment, such as tillers and discs, when the contamination is surficial; mixing with vertical augers; and injection grouting. With all of these methods, the stabilization reagent is typically added to the surface of the soil to be treated and blended or mixed into the soil with one of the above methods.

Ex situ methods are similar to *in situ* methods except that the soil is usually stockpiled prior to treatment. *Ex situ* methods also include the use of pug mills and specialized mixing equipment, such as road reclaimers. In most cases, *ex situ* treatment can be performed at a higher rate (tons per day) than *in situ* treatment. With either method, the goal is to create a homogeneous mix between the impacted soil and the stabilization agent.

Post-treatment performance verification testing will depend on the regulatory program. At a minimum, testing will include analyzing for TCLP-lead (and other metals present). Common testing frequencies vary from one for every 250 cubic yards of soil, to one for every 500 cubic yards. Optimally, the sampling frequency is based on the daily throughput of the operation of selected technologies. In addition, SPLP and other leaching tests should be performed based on the specific regulatory program. Following stabilization, samples for total metals analysis are collected to provide verification that the site-specific remediation goals are met.

5.4.1 Costs/Benefits of Stabilization

When comparing stabilization with other firing range remediation methods, several factors need to be considered:

- What is the long-term use of the firing range?

- Is cost-effective landfill space available?
- Can stabilized soil be disposed on site in an area that could be managed to prevent human contact with the material?

As described in previous sections, stabilization is more robust than solidification. Stabilization is also typically more cost-effective. Other technologies, including thermal extraction and chemical extraction (i.e., acid washing), also tend to be more costly. Table 5-1 on page 52 compares the costs for various types of metals remediation.

Table 5-1 indicates that stabilization can be a cost-effective approach to lead remediation. For comparison with other alternatives, transportation and disposal costs are also often added in. This may not be appropriate in all cases. As discussed in the next section, the bioavailability of stabilized soil is often less than that of soil that has not been amended. Also, stabilized soil has been shown not to be a threat to groundwater, and direct contact issues can be addressed through low-cost soil covers. Evaluation of on-site versus off-site disposal can be performed, based on the costs involved and the long-term plans for the firing range.

5.4.2 Public Acceptance of Soil Stabilization

The general public is concerned about the following issues:

- Environmental conditions may affect the long-term immobilization of contaminants, and there is concern that the process under certain circumstances could be reversed. Long-term monitoring is necessary to ensure that contaminants have not been remobilized.
- Future use of the site and environmental conditions may erode the materials used to stabilize contaminants, thus affecting their capacity to immobilize contaminants. Solidified material may also restrict future use of the site.
- Depth of contaminants may limit these processes.

Among the concerns regarding solidification are these:

- In general, stakeholders desire low-temperature, nonoffgas-producing stabilization technologies that generate no secondary wastes, minimize disposal volumes, and ensure long-term durability.
- Institutional controls provide little confidence in a remediation project from a stakeholder's point of view.
- It is well documented that inorganic salts affect the set rate, through either acceleration or retardation. End users need to know precisely how different salts individually and collectively affect basic Portland cement stabilization so that the proper additive can be used in the dry binder mix.
- Special concerns may be posed by other types of hazardous waste (e.g., organic chemicals) that may interfere with the solidification/stabilization process: inorganic acids that will decrease durability for Portland Type I cement; chlorinated organics that may increase set time and decrease durability of cement if concentration is too high; and oil and grease that will decrease unconfined compressive strength.
- Several soil characteristics influence whether the technology will contain the waste effectively. These characteristics include void volume, which determines how much grout

or cement can be injected into the site; soil pore size, which determines the size of the cement particles that can be injected; and permeability of the surrounding soil, which determines whether water will flow preferentially around the solidified mass.

- Some cementation (solidification) processes result in significant increase in volume (up to double the original volume).
- Certain wastes are incompatible with variations of this process. Treatability studies are generally required. Reagent delivery and effective mixing are more difficult than for *ex situ* applications.
- Cracks extending through the stabilized mass have been observed in some demonstrations, the cause of which is suspected to be the high temperature rise during curing.

5.5 Chemical Extraction

As with any treatment technology, soil parameters play a significant role in the success of the technology. For chemical treatment, these include but are not limited to the following:

- **Feed soil pH and buffering capacity** determine the volume of chemical addition to reach the pH required for efficient leaching.
- **Cation exchange capacity (CEC)** indicates the ability of the soil to bind lead in an exchangeable form. Generally, CEC is proportional to the clay content of the soil, making sandier soils easier to treat.
- **Total organic carbon** indicates the volume of organic material (humates) present in the soil on a weight-to-weight basis. Dissolved metals complexed with humates are difficult to remove and may require a separate humate-removal step prior to chemical leaching.
- **Iron and manganese levels** indicate the presence of iron and manganese oxides that can adsorb lead. These materials tend to bind lead very strongly and may leach out with other metals, increasing overall chemical consumption during leaching and precipitation steps.

These parameters provide some indication of difficulties that may be encountered during leaching. The leachant selection and optimization process can be further focused, if required, by determining heavy-metal speciation and binding mechanisms in the soil. These tend to be rather expensive analyses and may not be required at every site, as outlined in Table 5-1.

Heavy-metals speciation indicates the types of chemical compounds the metals are present as. At many SAFRs containing native alkalinity, lead is present predominantly as elemental lead and carbonate minerals. These lead carbonate formations are much easier to leach than elemental lead, which exists predominately as free particulates in the soil matrix. As such, any leaching steps should be performed only after the particulate lead has been removed using physical separation techniques. Lead oxides and lead sulfate are other lead compounds that may occur under certain conditions and are very difficult to leach. Soil containing a high percentage of these compounds may be more amenable to stabilization than chemical leaching.

All of these parameters should be evaluated in a thorough treatability study prior to field mobilization. Once treatability results have been determined, a sequential approach can be developed for coupling appropriate technologies to address site-specific conditions with an optimized approach.

5.5.1 Public Acceptance of Chemical Treatment Technologies

Public concerns include the following:

- While metals that are mixed and bound with organic contaminants can be extracted, the residuals may be restrictive of future land use.
- The toxicity of the solvent is an important consideration as traces may remain in the treated soil.
- After acid extraction, any residual acid in treated soil needs to be neutralized.
- In solvent extraction, impermeable membrane liners and covers should be used to reduce solvent evaporation and to protect against rain.

5.6 Asphalt Emulsion Batching–Encapsulation

The soil to be treated with emulsions is contaminated with metals and organic contaminants and will subsequently be used as an asphalt sub-base for paving projects. As such, the following parameters must be addressed:

- chemical fixation/treatment effectiveness
- physical properties of treated soil

Ultimately, the goal of the treatability study is to provide a mix design and procedures for field implementation that meet the site reuse goals for treated soils as well as the physical characteristics to support the soil's intended end use.

Since the treated soil is to be used as a product, particulate metals must be removed prior to emulsion treatment. This particulate-removal step is critical as encapsulated heavy-metal particles could be re-exposed during placement or subsequent work on the treated sub-base material. Also, certain metals like copper are detrimental to the asphalt matrix and must be removed to ensure the long-term structural integrity of the sub-base material.

To ensure effective particulate removal, all metal leachability testing will be done after the emulsion mix has cured, been strength tested, and the cured sample subsequently pulverized. The aliquot selected for leachability testing will be taken from the pulverized sample.

The initial required data includes

- grain-size analysis/containment by fraction,
- contaminant removal by size segregation and gravimetric techniques,
- oversize fragment removal by size segregation and screening, and
- post-treatment and TCLP metal results for each individual size fraction.

A treatability study as outlined in Appendix D is required to focus first on material characterization of the sample, followed by optimizing treatment of specific fractions using physical treatment methods. Recoverable quantities of metals will be estimated in the treatability study to quantify the amount requiring recycling. Once completed, residual soils free of particulate metals will undergo subsequent emulsion treatability studies. This approach is favorable from a cost standpoint, as described in Table 5-1.

5.6.1 Public Acceptance of Asphalt Emulsion Chemical Treatment Technologies

Among the issues that affect public acceptance of this technology are the following:
- Future use of the site and environmental conditions may erode the material used to encapsulate contaminants, thus affecting their capacity to immobilize. Stabilized material may also restrict future use of the site.
- Certain waste streams are incompatible with variations of these processes, and each application must be carefully tested for long-term compatibility before it is used.
- Special concerns may be posed by other types of hazardous waste (e.g., organic chemicals) that may interfere with stabilization processes. Some factors include inorganic acids that will decrease durability of the emulsion, or chlorinated organics that may increase set time and decrease durability of the emulsion if the concentration is too high.

5.7 Phytoextraction and Stabilization Approaches (Constructed Wetlands)

A passive wetlands system could be designed to receive storm water runoff from small arms firing ranges. The constructed wetlands could be placed at either the toe of the berm slope so as to receive sheet flow runoff from the berms, or designed to receive storm water through channels that contain and direct storm water runoff. The wetlands could be designed in combination with biofilters (using the storm water channel as prefilters to remove large particles prior to polishing in the wetlands) and/or detention basins to allow the settling of large particle sediments prior to discharge of the storm water into the constructed wetlands. The designed slope for such systems should be between 1% and 5% (USEPA, 2000). In circumstances where the supporting water is acidic, anoxic limestone drains or other mechanisms can be installed between the berm and the wetlands to raise pH and allow for lead precipitation, thereby increasing retention in the wetlands.

As part of a conceptual constructed wetlands to address arsenic, chromium, and copper dissolved in storm water at a site in Florida, modifications to storm water channels and retention basins were proposed. The anticipated effect was to reduce storm water infiltration and increase storm water residence time through the installation of a low permeability liner to the channel and/or the basin, followed by the planting of wetlands vegetation to develop the organic base for retention of the metals. Initially, excavation and grading of the existing channel and basin would be performed to contour the subgrade. The channel and basin would be lined with a low permeability liner, consisting of a geosynthetic clay liner (GCL) or compacted low permeability soil (e.g., clay). Vegetative soil material (e.g., topsoil) would be placed above the liner and further covered with a layer of humic material (*Sphagnum* or peat moss) to facilitate organic binding of metals. Soils would be a sandy loam and contain approximately 8% to 10% organic matter. The channel basin would be planted with a combination of native emergent wetlands species that are known to remove metals from surface water.

5.7.1 Public Acceptance of Phytoextraction Technologies

Among the issues expected to affect public acceptance are the following:

- The long-term effectiveness of constructed treatment wetlands is not well known. Wetlands aging may contribute to a decrease in contaminant removal rates over time.
- Constructed wetlands do not destroy the metals; they restrict their mobility. Certain conditions such as pH, temperature, or other variables may lead to a reversal of the filtration process for metals.
- During operation of the constructed wetlands, wildlife may be adversely affected by the presence of metals that have accumulated in plants and sediment.
- The outlet of the constructed wetlands should be carefully monitored. Underlying aquifers must also be monitored to assure that the impermeable base has not leaked.

6.0 ISSUES, CONCERNS, AND RECOMMENDATIONS

6.1 Risk Assessment

Interdependent risk assessments often are conducted for human and ecological receptors potentially exposed to contaminants in shooting range media. While differences in methods and assumptions justify separate analyses, several considerations are common to both types of risk assessments. Aside from the federal requirements under RCRA and Superfund, many states have methodologies developed according to authorized programs such as RCRA and state-developed remediation, cleanup, or mitigation programs. The variability in risk assessment approaches, as identified by the ITRC Small Arms Firing Range Team, is quite high. ITRC has formed a 2003 team to address risk issues such as these.

6.2 Site Identification

Some state agencies are informally collecting information on the location of outdoor shooting ranges. Owners of closed ranges should be required to notify state agencies if they become aware of soils on site that are present in amounts that pose a risk based on current or reasonably anticipated future land use or if exceedances of groundwater quality standards are detected. See Section 4.4, Remediation/Future Use Issues.

6.3 Berm Reuse

At some ranges, it may be possible and desirable to reuse the soil from the backstop of a range that is being closed to construct a new berm or rebuild an existing berm located in another area of the same property or facility. It is USEPA's position that ranges that reclaim and recycle lead bullets or lead shot may place the soil that is generated during the reclamation process back onto an active range on the same property or facility or a property adjacent to and under the same ownership as the property where the soils originated, without testing the soil for hazardous waste characteristics.

It has been suggested that range soil from a former backstop may also be reused, following lead reclamation, for constructing or rebuilding a backstop at a location that is not on the range property. The same environmental benefits from berm reuse as described earlier in this document could be realized, but extra oversight may be needed. Since individual states may not permit this action or may impose additional requirements for transportation, documentation, and approvals, state regulators should be consulted prior to transporting range soils to a property that is not the same as or adjacent to and under the same ownership as the property where the soils originated.

6.4 Cleanup Criteria

Current models used to establish safe cleanup levels at SAFRs use either residential or industrial exposure as a basis. Many of the BRAC (Base Realignment and Closure) sites have become more dispersed recreational areas (i.e., wildlife refugees, open spaces, etc.) that have deed restrictions prohibiting development. None of the existing criteria take this type of restricted use into account when establishing cleanup criteria. The exposure pathways for dispersed recreation are much different, and exposure rates are lower than for residential or industrial exposure scenarios.

6.5 Sample Preparation

While many current analytical methods rely on using only soil that has passed uncrushed through a 30-mesh sieve as the source for analytical tests, some controversy exists in the field as to the best method(s). Other sample preparation protocols have been proposed and approved by governing regulatory bodies. Differences in sample preparation protocols include the designation of the size of sieve to use or whether to use a sieve at all and on the degree of disaggregation prior to sieving. Therefore, the recommendation of a specific sample preparation method may be misleading. The choice of a method should result in a sample that is representative of the site and its environment and is agreeable to the regulatory community and other parties involved in the evaluation.

6.6 Technologies

- Establishing physical treatment operations within the confines of the small arms firing range is ideal. Locating the treatment plant in the range facilitates the timely excavation and haulage of soils destined for treatment, as well as the return and placement of treated soil. When fieldwork is confined to one location, the project is more efficient and overall project costs are reduced.

- Long-term effectiveness has not been demonstrated for many contaminant/process combinations.
- Depth of contaminants may limit these processes.

- Institutional controls provide little confidence in a remediation project from a stakeholder's point of view.

6.6.1 Soil Washing

- The clean portion of separated soil must be analyzed for residual contamination before it is used as clean material. Sites using soil washing should have on-site capability to test samples of treated soil before it is released as clean. Some states may require certified labs to be used for these tests.

- Soil contaminated with both metals and organic compounds make formulating a single suitable washing solution difficult. Sequential washing using different wash formulations may be required. Soil-washing processes for soil contaminated with volatile organic compounds (VOCs) may require emission controls.

- Wash water containing inorganics may require treatment before it can be discharged, as it is usually not completely free of smaller organic particles.

- Measures should be taken to prevent wind-borne particulates if dry screening is a step in the process.

- Based on the results and implementation of the treatability study findings for the design of the soil-washing plant, it is strongly recommended that every soil-washing solicitation include a vendor-conducted, bench-scale treatability study for effective costing and plant design. The bench-scale treatability study represents an effective method for fully defining a remediation problem, associated treatment parameters, and plant design.

- Establishing physical treatment operations within the confines of the small arms firing range is ideal. Locating the treatment plant in the range facilitates the timely excavation and haulage of soils destined for treatment, as well as the return and placement of treated soil. When fieldwork is confined to one location, the project is more efficient and overall project costs are reduced.

6.6.2 Stabilization

- Environmental conditions may affect the long-term immobilization of contaminants, and there is concern that the process, under certain circumstances, could be reversed. Long-term monitoring is necessary to ensure that contaminants have not remobilized.

- Future use of the site and environmental conditions may erode the materials used to stabilize contaminants, thus affecting their capacity to immobilize contaminants. Solidified material may also restrict future use of the site.
- Certain waste streams are incompatible with variations of these processes, and each application must be carefully tested for long-term compatibility before it is used.

- Depth of contamination may limit this technology.

6.6.3 Solidification

- It is well documented that inorganic salts affect the set rate, through either acceleration or retardation. However, end users need to know precisely how different salts individually and collectively affect basic Portland cement stabilization so that the proper additive can be used in the dry binder mix.

- Special concerns may be posed by other types of hazardous waste (e.g., organic chemicals) that may interfere with the solidification process, including inorganic acids that will decrease durability for Portland Type I cement; chlorinated organics that may increase set time and decrease durability of cement if concentration is too high; and oil and grease that will decrease unconfined compressive strength.

- Several soil characteristics influence whether the technology will contain the waste effectively. These characteristics include void volume, which determines how much grout or cement can be injected into the site; soil pore size, which determines the size of the cement particles that can be injected; and permeability of the surrounding soil, which determines whether water will flow preferentially around the solidified mass.

- Some cementation processes result in significant increase in volume (up to double the original volume).

- Certain wastes are incompatible with variations of this process. Treatability studies are generally required. Reagent delivery and effective mixing are more difficult than for *ex situ* applications.

- Cracks extending through the stabilized mass have been observed in some demonstrations, the cause of which is suspected to be the high temperature rise during curing.

- In general, stakeholders desire low-temperature, nonoffgas-producing stabilization technologies that generate no secondary wastes, minimize disposal volumes, and ensure long-term durability.

- While metals that are mixed and bound with organic contaminants can be extracted, the residuals may restrict future land use.

- The solvent’s toxicity is an important consideration as traces may remain in the treated soil.

6.6.4 Chemical Extraction

- After acid extraction, any residual acid in treated soil needs to be neutralized.

- In solvent extraction, impermeable membrane liners and covers should be used to reduce solvent evaporation and to protect against rain.

- While metals that are mixed and bound with organic contaminants can be extracted, the residuals may restrict future land use.

- Solvent toxicity is an important consideration as traces may remain in the treated soil.

6.6.5 Asphalt Emulsion Chemical Treatment Technologies

- Future use of the site and environmental conditions may erode the materials used to encapsulate contaminants, thus affecting the materials' capacity to immobilize. Stabilized material may also restrict future use of the site.

- Certain waste streams are incompatible with variations of these processes, and each application must be carefully tested for long-term compatibility before it is used.

- Special concerns may be posed by other types of hazardous waste (e.g., organic chemicals) that may interfere with stabilization processes, including inorganic acids that will decrease durability of the emulsion and chlorinated organics that may increase set time and decrease durability of the emulsion if the concentration is too high

6.6.6 Phytoextraction Stabilization Technologies

- The long-term effectiveness of constructed treatment wetlands is not well known. Wetlands aging may contribute to a decrease in contaminant removal rates over time.

- Constructed wetlands do not destroy metals; they restrict their mobility. Certain conditions such as pH, temperature, or other variables may lead to a reversal of the filtration process for metals.

- During operation of the constructed wetlands, wildlife may be adversely affected by the presence of metals that have accumulated in plants and sediment.

- The outlet of the constructed wetland should be carefully monitored. Underlying aquifers must also be monitored to assure that the impermeable base has not leaked.

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APPENDIX A

Case Studies

Adapting Remedial Technologies to Meet Site-Specific Risk-Based Cleanup Goals
A Case Study of the MCA/GCC 29 Palms Range Soil Remediation Project

Michael F. Warminsky
mike.warminsky@amec.com

Live-fire training is an integral part of our war fighters' training and is essential for maintaining mission readiness. In all, the Department of Defense expends over 2 million pounds of lead annually to maintain this vital, necessary training function. Unfortunately, environmentalists are continuing to press for cessation of live-fire training, using lead contamination as the reason. These issues are compounded by the fact that a replacement bullet trap must be retrofitted to existing berm areas with minimal impact to ongoing live-fire training.

At MCA/GCC, Brice Environmental Services Corporation is working in conjunction with Battelle Memorial Institute (Battelle) and the Naval Facilities Engineering Service Center (NFESC) to configure a soil-washing system to physically remove particulate lead from range soil and meet the risk-based cleanup requirements at the site. This approach was based on a comprehensive treatability study, which indicated the particulate contaminants could be isolated in a small fraction of the total range soil, enabling their effective removal using density separation techniques borrowed from the mining industry. This innovative approach allowed for successful completion of the project ahead of schedule and within budget, while rendering range soil suitable for reuse during subsequent berm construction and generating 230 tons of high-quality metals for recycling.

BACKGROUND

The overall scope of this proactive pollution prevention project included removing and processing contaminated soils from three small arms firing ranges to remove the lead, then installing bullet traps at those ranges as a pollution prevention measure. During the site assessment performed by Battelle, it was determined that surficial lead concentrations ranged from 27,000 mg/kg to 233,142 mg/kg, with concentrations rapidly decreasing with depth. Based on depth profile data and surface data, it was determined the lead at the small arms ranges is essentially immobile except when surface materials are carried away by wind and water erosion.

Battelle used site-specific data as input values to determine an acceptable soil concentration for an industrial worker (a Marine) exposed to the soil 8 hours/day, 5 days/week. To determine an acceptable soil-lead concentration, the Blood Lead Spreadsheet, Version 6 ("LeadSpread"), developed by the California Environmental Protection Agency, Department of Toxic Substances Control (DTSC), was used. The LeadSpread model gave the value of 5,451 µg/g (mg/kg). This value was rounded down to 5,400 mg/kg to provide a conservative soil-processing goal.

Because this range maintenance and repair work was performed on an active range, USEPA's Military Munitions Rule (40 CFR, Part 260) applied, and the soils were not considered hazardous waste under the Resource Conservation and Recovery Act (RCRA). The local regulators were also in favor of adopting this position and did not apply the California hazardous waste regulations (CCR Title 22).

TECHNOLOGY SELECTION

To capitalize on the favorably negotiated risk-based cleanup goals, a technology to selectively remove particulate metal contaminants was required. Since the cleanup goal was a function of total lead levels, traditional stabilization methods were discounted, as they do not reduce total lead levels. Also, the all-or-nothing approach of off-site disposal was not used, as it did not mitigate the problem. Rather, it only transferred the liability associated with lead in soil to an off-site location and required replacement fill to be imported to use in subsequent berm construction.

The ideal technology for total lead reduction in soil is soil washing. The key to successful soil washing is to couple wet-screen sizing with gravity separation to selectively remove lead from only those fractions requiring it. The Brice soil-washing process is based on placer mining techniques that have been in use for over 100 years in the mineral dressing industry. Taking basic placer mining techniques and unit operations, Brice modifies and configures unit operations to provide both clean soil (traditional placer “tails”) as well as refined lead concentrate suitable for recycling. A logic diagram outlining the technology selection process is detailed in Figure 1.

Physical Sizing

The physical sizing process uses sequential wet-screening steps, the first of which is deagglomeration. Wet screening provides dust-free operation and sharp particle-size fraction cuts. For each screening step, “plus” and “minus” fractions are generated, with actual cut points based on the treatability study data. The goal of wet screening is to partition the particulate metal contamination into narrow-size fractions to facilitate effective gravity separation and remove from the process plant those soil fractions not requiring any treatment.

The sand and gravel fractions typically represent the largest portion of range soils. These fractions also contain the majority of the lead (typically over 95%) as free particulates. This particulate lead is easily removed using mining-based techniques, which concentrate the lead into a refined product for recycling and renders the soil suitable for reuse.

The silt/clay fraction of range soils typically contains a small portion of the total lead in the form of surficial ionic metal coatings. In some cases, sizing and gravity separation of the sand and gravel fractions may remove sufficient lead to render the whole matrix suitable for reuse. In others, the surficial ionic coatings may have to be removed using additional physical/chemical treatment steps to meet cleanup goals.

Gravity Separation

When particulate contaminants are the same size as the surrounding soil particles, gravity separation is used to remove the particulate metal. Elutriation and jigging are typically used for soil fines removal and gross particulate lead removal, respectively. Elutriation uses water flow over weirs to separate soil fines from larger sand particles. Jigging uses differential settling in water to separate heavy bullet particles from same-size, but lighter, sand/gravel particles. This approach removes the particulate lead from the sand and gravel fractions.

Dewatering

To close the loop on water consumption, process water is recycled within the plant. A clarifier and mechanical dewatering equipment is used to aggressively dewater the fines and enable the reuse of process waters. Recycling the plant process water minimizes both water consumption and the ultimate volume of water requiring treatment, limiting it to just the static volume of the plant at project completion.

Acid Leaching

If physical/gravity treatment of the sand and gravel fractions is insufficient in meeting cleanup goals, the silt and clay fractions can be effectively treated with acid leaching. A dilute hydrochloric acid solution dissolves leachable ionic metals coatings from the soil fines (and sands if required), creating metal-chlorides in solution. The dissolved metals are precipitated out of solution, dewatered, and removed from the process for recycling at a smelter. The lixiviant is re-acidified and recirculated within the plant. The treated soil fractions are then dewatered, neutralized, and recombined with the rest of the treated soil matrix.

QA/QC Sampling and Sample Preparation Procedures

Proper sampling and sample preparation methods must be used when dealing with soils containing particulate metal ranging in size from intact bullets to very fine fragments. These methods are necessary to reduce sample variation and ensure adequate material representation in the aliquot being analyzed.

Sampling and sample preparation protocols developed by the mining industry are appropriate for soils from small arms shooting ranges. This involves taking samples sized according to the diameter of the largest piece in the material, followed by sample preparation according to the type of analysis to be performed, (i.e., total lead or TCLP lead). For range soils with particles as large as 3/8th of an inch, sample sizes are typically 300 pounds or more.

Mining-based sampling and sample preparation adds costs to the project, but these costs are less than the costs associated with schedule impacts caused by reprocessing material as a result of data scatter and not achieving data quality objectives because of statistically unrepresentative samples.

Lead Recycling

During firing range maintenance or remediation activities, recovery of bullets and bullet fragments from firing range sands or soils via physical treatment constitutes “reclamation” per 40 CFR 261.1(c)(4). Metal concentrates reclaimed from firing range berms via size classification and density concentration contain more than 90% metal on a dry weight basis. The primary metal is lead, with small amounts of copper and antimony. The concentrate reclaimed from the firing range material is “scrap metal” per 40 CFR 261.1(c)(6). Under 40 CFR 261.6(a)(3)(iv), 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 specified in paragraphs (b) and (c) of 40 CFR 261.6. Therefore, the scrap metal reclaimed from the firing range sand, or soil, does not need to be regulated or manifested as a hazardous waste during generation or transport to a smelter for recycling.

SITE OPERATIONS

Brice Environmental Services performed remedial operations as a first-tier subcontractor to Battelle, under their prime contract Number N47408-95-D-0730. The scope of work for Brice on this project included both a bench-scale treatability study and subsequent full-scale treatment of range soils. The project objectives were to meet the treatment goal of less than 5,400 mg/kg lead in the processed soil while recovering particulate metal from the soil at a purity level suitable for recycling.

The bench-scale treatability study test results indicated that the majority of the lead contamination ranged in size from large intact bullets and bullet fragments (¾-inch to ¼-inch) to sand-size (50-mesh) metal particles. The treatability study results further indicated that residual lead levels would average around 1,600 mg/kg in the treated soil after removal of free particulates in the ¾-inch by 50-mesh range. Since this level was considerably less than the treatment goal of 5,400 mg/kg, no further particulate recovery steps were required or deployed, reducing total project costs accordingly.

Deploying only the required unit operations is critical to project cost control, as incremental treatment costs follow the law of diminishing returns, with successively smaller contaminant removal increments costing increasingly more to attain. Figure 2 outlines soil-washing costs as a function of treatment goals for several completed projects.

The plant subsequently deployed at 29 Palms was based on the treatability study results and consisted of individual unit operations integrated into one continuous process. Since the treatability study results indicated that site soils were composed primarily of sands and rock, the process was designed to separate rock larger than ¾-inch and sand smaller than 50-mesh from the soil fraction containing the targeted particulate metals.

To accomplish this, a wet vibrating screen deck containing a ¾-inch screen (Step 1) was utilized to remove large particulate-free rock. A second smaller screen (4-mesh) on the vibrating screen deck was utilized to separate the larger particulate metal and rock from the fine soil fraction. Fine particulate metal and fine soil (minus 4-mesh), along with the wash water passed through the smaller screen deck.

The minus ¾-inch by plus 4-mesh metal and rock (Step 2) was subjected to density treatment. Following density treatment, the separated rock was discharged to a dewatering screw (Step 3) and discharged from the plant.

The slurry of material that passed through the second screen was pumped to a separate density treatment unit (Step 4) for fine particulate metal recovery. Refining the metal in this fraction was crucial to maximize the value of the material. Recovered metals from this step were thus discharged to two additional density recovery units to enhance the purity of the metal (Steps 5 and 6). The concentrates from these units, along with the concentrates from Step 2, were piped to a metal dewatering unit (Step 7). From this unit, the concentrate was dewatered and discharged into a "supersack" for subsequent recycling by the Base Defense Reutilization and Marketing Office (DRMO).

Soil fines discharging from Step 4 was split into clay and fine sands in another dewatering screw (Step 8). Density-treated sands from Step 5 and 6 were also discharged to the dewatering screw for dewatering. Soil clays exiting the screw overflow were pumped into a clarifier (Step 9), where a coagulant was added to accelerate the settling rate of the clays. The dewatered clay was then pumped to a centrifuge for additional dewatering (Step 10). All of the ¾-inch minus treated soil fractions were recombined and placed into a daily stockpile to await confirmation sample results and subsequent reuse in bullet-trap construction. The ¾-inch plus rock was stockpiled separately for reuse as erosion control or road base material in subsequent base civil engineering projects.

Approximately 11,700 tons of soil was processed, resulting in the generation of approximately 230 tons of recovered metal concentrates. Analysis of the concentrate showed it to average approximately 90% metal. Of the metal, approximately 85% was lead, 13% copper, 1% zinc, and 1% antimony. The average total lead in feed soils was 24,700 mg/kg lead. Processed soils were analyzed in daily batches with the average lead level in treated soil less than 1796 mg/kg, or just 33% of the risk-based cleanup goal.

SUMMARY

The objective of the 29 Palms project was to remove particulate metal from approximately 11,700 tons of range soil within a tight schedule, while attaining a cleanup standard of less than 5,400 mg/kg total lead. These objectives were met, with the average total lead in the treated soil less than 1,796 mg/kg and plant throughput averaging between 20 and 30 tons/hour.

This adaptation of mining-based technology for removing particulate metal is an inexpensive means of both reducing the threat of ricochets at active ranges and mitigating lead contamination at ranges to be closed. At 29 Palms, the total soil-processing cost for the project was approximately $66.30 per ton, which included all mobilization, processing, and demobilization costs. In all, 230 tons of particulate metal was recovered (with an approximate purity of 90%) and recycled by the base DRMO.

For this project, sizing and gravity separation as a stand-alone treatment process was all that was required to meet cleanup goals. Other sites may require additional gravity separation steps, aggressive deagglomeration, and/or residual chemical treatment to meet more stringent cleanup goals. Examples of completed projects where soil washing met more stringent goals for range soil treatment include Bergstrom Air Force Base, Fort Polk, Naval Weapons Station Earle, and the Twin Cities Army Ammunition Plant, where total lead reuse goals were 1,000, 500, 400, and 300 mg/kg respectively.

In these cases, the process was modified with additional treatment steps based on site-specific treatability study results. Ongoing projects with soil-washing operations similar to MCA/GCC 29 Palms include small arms ranges at Camp Edwards/MMR and Range 24 at Fort Dix.

The 29 Palms project was an unparalleled success for three important reasons:

- The solicitation required that a vendor-based, bench-scale treatability study be performed prior to mobilization. This was the best investment to ensure full-scale success because bench-scale treatability studies allow the vendor to evaluate site-specific process parameters for the purpose of delineating the process approach and costs. By conducting these studies, the vendor is placed in a position of decreased risk and can price the remediation with fewer contingencies.
- The design of the treatment train incorporated flexibility for changing components based on actual soil conditions. The plant was modified in the field to meet changing soil conditions, subsequently increasing both removal efficiency and production rate without impacting the project schedule.
- The project succeeded because of the willingness of all parties to work together as a team with a common objective—identifying and mitigating potential project impacts before they occurred.

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Figure 1: Treatment Train Decision Tree for Small Arms Firing Ranges

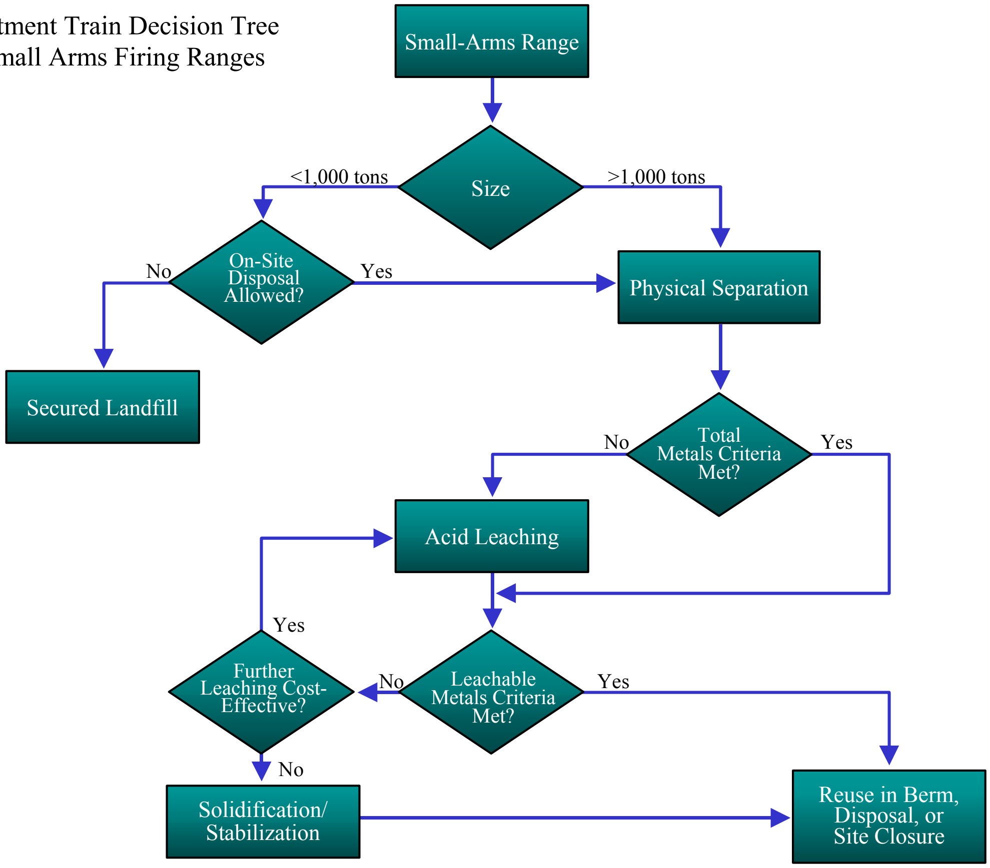
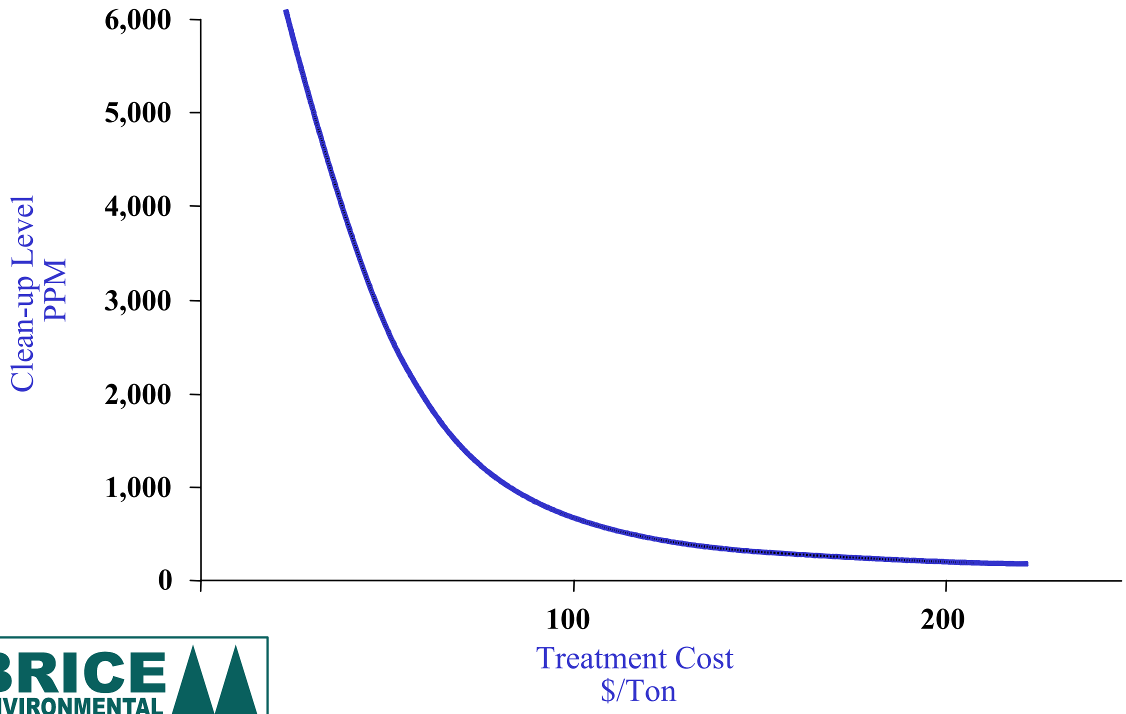


Figure 2: Relative Soil-Washing Cost as a Function of Cleanup Goal



Fort Dix gets lead out at firing range

(Published in the *Asbury Park Press* 9/25/99)

By KIRK MOORE
STAFF WRITER

FORT DIX -- A crew of former Alaskan gold miners is using its know-how to dig up to 1,000 pounds of lead bullets a day from an Army firing range here in a demonstration project military engineers hope will show how to remove toxic lead contamination at nearly 3,000 ranges around the country.

At Fort Dix's Range 24, machinery originally designed for the gold fields is processing sand from the range berm, the sandy wall behind the target area that catches spent bullets. Engineers estimate the soil is 1 percent to 2 percent lead by weight. Lead is poisonous heavy metal that has to be cleaned up.

BOB BIELK photo

Joan Brice of Brice Environmental Co., Fairbanks, Alaska,

"We have trained over 3 million soldiers here in the last 82 years . . . from the First World War to World War II, Korea, and Vietnam," said Fort Dix commander Col. James Snyder.

With the Army Reserve, National Guard, and police training that continues today, that adds up to a lot of buried bullets.

Cleaning them up is a major step toward what the Army calls "greening the ammunition"—a complete phaseout of lead, the metal that's been used in bullets since American soldiers leveled flintlock muskets against the British 224 years ago.

Tungsten will replace lead in the first 1 million rounds of replacement ammunition being produced for the Army's M-16 rifles at the Lake City Army ammunition plant near Independence, Mo. this year, said Wade Bunting, program manager for the Green Bullet project at Picatinny Arsenal in Morris County.

"It's a direct replacement" for lead because tungsten is a slightly denser metal, Bunting said. The tungsten is lightened somewhat by the addition of tin or nylon plastic during the molding process, so the new ammunition will perform the same as the old bullets, he added.

The military's work on tungsten ammunition next year will expand to studying how to make tungsten shotgun pellets cheaply, which in time could give civilian shooters an affordable alternative to steel shot, said James Frankovic, manager of the RangeSafe cleanup program based at Picatinny.

The military’s wakeup call on lead contamination came several years ago when the U.S. Environmental Protection Agency demanded a halt to training at the Massachusetts Military Reservation on Cape Cod, Frankovic said. Serious lead contamination and groundwater problems were traced to firing ranges at the Massachusetts base, and Bunting said those ranges are getting the first consignment of 125,000 tungsten bullets.

Meanwhile, Picatinny engineers have sought cheaper, more environmentally safe ways to clean up existing lead contamination and pave the way for new ammunition. The $1.7 million Fort Dix project is unique because it uses no harsh chemical or acid cleaning agents but only water and a polymer-based clarifying chemical that’s also used to treat drinking water, said Michael Warminsky of Brice Environmental Services Corp., the Army’s soil-washing contractor.

“There’s all kinds of bullets—.45 wadcutter (target ammunition), .30 caliber, .223 (M-16 bullets), and even a lot of buckshot,” Warminsky explained. “The bullets are easy. It’s these little lead particles that are hard to pick out.”

Some bullets break apart when they hit buried stones or spent bullets, Warminsky said. The lightweight, high-velocity M-16 bullet in particular “self-destructs. We found one place where they must have been doing machine gun practice, because there’s nothing but lead foil,” Warminsky said.

To sort it all out, the Brice crew digs soil from the berm with a front-end loader, carrying it to the first conveyor on their processing line. Washed with water, the soil passes through sorters that first eject any pebbles or other debris bigger than 3/4-inch, Warminsky said.

The screened soil is conveyed to a pulsing “density separator” that works on the same principle as panning for gold: Heavy metals sink faster than dirt.

“The pulsing momentarily suspends all the material . . . and lead, being heavier, sinks faster,” Warminsky said. Water and suspended dirt flow out, leaving most of the bullets in the separator tub.

Finally, the water goes to a clarifier, where a polymer-based floccing compound congeals the remaining fine silt.

The end products: One-ton packages of spent bullets to be shipped to the makers of Exide car batteries in Reading, Pa., who pay 6 cents a pound for lead, and newly washed sand that will go back onto the range berm.

After the range becomes tungsten-only, that sand will absorb M-16 bullets without breaking them up, and it’s possible the Army will start recycling bullets back to its munitions factories, Bunting said. The new bullets will cost about 1.5 cents more than lead at first, but over the years engineers estimate the real cost per cartridge will drop by 5 cents, he said.

Brice is a family-owned company, with roots in Alaskan bush construction and mining, and it applies mining techniques to soil decontamination around the country. The company has a contract to assess lead levels at the Monmouth County police academy range in Howell. “It’s just an assessment of the berm” and nearby perimeter road, said Leo Carling, county superintendent of buildings and grounds.

“We’ll see what they find and if we have to, we’ll clean it up.”

PROACTIVE Lead Removal AND POLLUTION PREVENTION

AT THREE SMALL ARMS RANGES

Daniel S. Janke, P.E. and Thomas C. Zwick
Battelle, Environmental Restoration Department
505 King Ave.
Columbus, OH 43201
janked@battelle.org or zwick@battelle.org
614/424-5875 or 614/424-6199

Leon Bowling
United States Marine Corps
Natural Resources and Environmental Affairs Directorate
Marine Corps Air Ground Combat Center
Box 788110 Building 1451
Twenty-nine Palms, CA 92278-8110
bowlingl@mcagcc.usmc.mil
760/830-7650 ext. 250

Barbara M. Nelson
Naval Facilities Engineering Service Center
ESC 411
1100 23rd Avenue
Port Hueneme, CA 93043-4370
nelsonbm@nfesc.navy.mil
805/982-1668

BACKGROUND

The Marine Corps Air Ground Combat Center (MCAGCC), located in south central San Bernardino County, California, is an active military facility. In 1940, the Army began using the base to train glider crews and, beginning in 1943, fighter pilots. The Navy used the facility for bombing and gunnery ranges until the end of World War II. The base was not in use between 1945 and 1952 but has been occupied by the Marine Corps since 1952.

In support of the primary mission of MCAGCC, troops are trained and qualified in the firing of rifles and pistols. The small arms range complex trains over 10,000 active duty Marines each year for service rifle and service pistol requalification. In addition, approximately 1,500 reserve Marines, local law enforcement personnel, Junior Reserve Officers Training Corps cadets, and recreational shooters use the small arms ranges each year.

The overall scope of this proactive lead removal and pollution prevention project included removing and processing contaminated soils from three small arms ranges to remove the lead, then installing bullet traps at those ranges as a pollution prevention measure. The ranges were in active use supporting weapons practice and qualifications requirements at MCAGCC.
The following ranges were specified for this project:

- Range 1: Known-Distance Rifle Range (“Rifle Range”)
- Range 1A: Battle Sight Zero Range (“BZO Range”)
- Range 2: Known-Distance Pistol Range (“Pistol Range”)

During the first phase of this project, Battelle characterized the ranges, performed an Environmental Assessment, established a soil-processing goal for total lead concentration based on a Human Health Risk Assessment, performed treatability studies, designed a soil management pad, and selected the appropriate soil-processing technology. During the second phase, Battelle constructed the soil management pad, removed contaminated soils from the ranges, selected and managed the soil-processing vendor, constructed infrastructure, and installed bullet traps at each of the three ranges.

SITE ASSESSMENT

In 1996 and 1997, the Naval Facilities Engineering Service Center (NFESC) performed an initial site assessment of some of the small arms ranges at MCAGCC. Results from the rifle range indicated that the highest total lead concentrations were in the impact berm and the area immediately behind the impact berm, with detected values of up to 35,000 mg/kg (all reported values from NFESC are after removal of visible lead fragments). The concentrations fell rapidly with distance behind the impact berm, falling to less than 1,000 mg/kg within 250 feet of the berm.

At the pistol range, the highest total lead concentrations were also in the impact berm, with detected values up to 4,300 mg/kg. As expected, the impact berm at the BZO range also had the highest total lead concentrations, with detected values up to 14,000 mg/kg. The concentrations behind the impact berms of both these ranges again fell rapidly with distance.

Lead concentrations also fell rapidly with depth. A location with a total lead surface concentration of 26,000 mg/kg had a concentration of 700 mg/kg two feet below ground surface. Based on the depth profile data and the surface data, the lead at the small arms ranges is essentially immobile except when surface materials are carried away by wind and water erosion.

Battelle performed an additional assessment during the summer of 1997. To avoid duplication of effort, the sampling and characterization plan prepared by Battelle worked in concert with the assessment performed previously by NFESC. The Battelle effort focused on complete characterization of the berms at the three ranges. The results of the Battelle effort are summarized in Table 1.

Table 1. Summary of Load Concentration Data at the Surface

Location	Mean Lead Concentration[(a)]
Rifle Range Berm	Total: 81,508 mg/kg <10 mesh: 32,258 mg/kg
Pistol Range Berm	Total: 233,142 mg/kg <10 mesh: 2,010 mg/kg
BZO Berm	Total: 27,021 mg/kg <10 mesh: 4,930 mg/kg

(a) Total lead concentration is the mean concentration for all sizes including whole bullets. The <10 mesh is the concentration of lead from small particles, once soils have been screened to removed the large bullet fragments and rocks.

Part of the sampling effort involved trenching into the various berms to determine the lead distribution throughout the berm. At the rifle range, bullets were found throughout the berm, suggesting that the berm had been rolled over or constructed from previously impacted soils. Based on our findings, the entire rifle range berm was removed for processing. The interior berm soils at the pistol and BZO ranges were essentially free of bullets. Analytical results confirmed the visual observations, so only 1 foot of soil was removed from the front, top, and back of these berms. The top 6 inches of soil in the areas behind the berms was also removed because of the large amount of visible lead in those areas. This 6-inch cut was taken 150 feet behind the rifle range and 50 feet behind the pistol and BZO ranges.

Part of the sampling and characterization work performed by Battelle included the collection of large representative samples for use in treatability studies. The largest samples were 55-gallon drums of bullet pocket soils and general (non-bullet-pocket) berm soils. Hazen Research in Golden, Colorado was subcontracted to process the large samples through a physical separation pilot plant. These representative samples provided a very useful understanding of the lead distributions in the various size fractions of the soil.

An observation made during the sampling effort was confirmed during characterization of these large samples. A large portion of the bullets found on the rifle range consisted of copper jackets only, or copper jackets with small pieces of lead clinging to the inside. The majority of the lead appeared to have corroded or weathered away, perhaps through galvanic action between lead and copper. About 62% of the lead was found in the ¾-inch by 10-mesh fraction. The remainder of the lead was reported as 26% in the 10 by 200-mesh fraction, and 11% in the minus 200-mesh fraction. The distribution appears to be consistent with the observation. The soil from the BZO range had a similar but less dramatic distribution of lead: over 77% in the ¾-inch by 10-mesh fraction, 19% in the 10 by 200-mesh fraction, and 4% in the minus 200-mesh fraction. Another on-site observation was that bullets found at the pistol range were intact, that is, they did not show evidence of corrosion. This observation is confirmed by the lead distribution: greater than 99% of the lead reported to the ¾-inch by 10-mesh fraction, and only a fraction of a percent in the finer fractions.

TECHNOLOGY SELECTION

Before selecting the soil-processing technology, it was necessary to establish the goal that the processing technology would need to achieve. Because this range maintenance and repair work was performed on an active range, the USEPA Military Munitions Rule (40 CFR, Part 260) applied, and the soils were not considered hazardous waste under the Resource Conservation and Recovery Act (RCRA). The local regulators were also in favor of adopting this position and did not apply the California hazardous waste regulations (CCR Title 22). Consequently, the soil-processing technology did not have to meet leachability and total metals criteria that would otherwise apply if the soils were classified as hazardous waste and were being disposed of off site. In addition, because the range will continue as an active range, criteria for cleanup scenarios in which the land might be returned to residential, commercial, or other military use did not apply.

The major concern at the site was the potential for human exposure to lead during normal range operations. Because the ranges remain in active use, the main receptors are Marines assigned to range duties. Lead exposure can occur if lead-containing dust is inhaled or inadvertently ingested. To determine an acceptable soil-lead concentration, the Blood Lead Spreadsheet, Version 6 ("LeadSpread"), developed by the California Environmental Protection Agency, Department of Toxic Substances Control (DTSC), was used. The LeadSpread model is an Excel™ spreadsheet that calculates blood-lead concentrations resulting from five different exposure pathways (dietary intake, drinking water, soil and dust ingestion, inhalation, and dermal contact). The spreadsheet also back-calculates a preliminary remediation goal for soil that would result in a blood-lead level of 10 µg/dL, for a given exposure scenario and for a specific set of input values.

Site-specific data were used as input values to determine an acceptable soil concentration for an industrial worker (a Marine) exposed to the soil 8 hours/day, 5 days/week. The LeadSpread model gave the value of 5,451 µg/g (mg/kg). This value was rounded down to 5,400 mg/kg to provide a conservative soil-processing goal.

When considering range remediation projects, Battelle uses the following logic for selecting the most cost-effective processing technology. If the quantity of material is small (e.g., less than 1,000 tons), then the material is simply disposed of in a secured landfill. If the quantity of material is large enough for processing to be cost-effective, then physical separation of the particulate lead is the first technology considered. If physical separation alone is not able to meet the total metals criteria, then acid leaching is used to further remove lead not susceptible to physical removal. After achieving the total metals criteria, the leachable metals criteria, if applicable, must be met. It is often necessary to further reduce the total metals concentrations to meet the leachable metals criteria. If further leaching is not cost-effective or if the leachable metals criteria cannot be met by leaching, then solidification/stabilization is used to meet the leachable metals criteria. This logic is the most basic approach used. Site-specific conditions and economics must always be considered in the final analysis.

Based on our knowledge of the lead distribution in the various size fractions of the contaminated soil and the results of the physical separation treatability studies, Battelle determined that physical separation could easily remove enough particulate lead to meet the soil-processing goal.

No other treatment was required. A performance specification for physical separation was developed using the results obtained during the first phase of the project.

SOIL PROCESSING

A soil management pad was designed and constructed to serve as (1) a staging area for soils to be processed, (2) a staging area for processed soils awaiting verification results, (3) a staging area for lead-bearing materials awaiting recycling, and (4) an area for the soil-processing operation. About 7,800 cubic yards (11,700 tons) of contaminated soils was excavated and stockpiled on this large (300-foot by 300-foot) asphalt pad. The pad was bermed with an asphalt curb to contain water. The water was collected in a sump and reused in the process. Electric power and water were brought to the soil management pad, which was located in an area that was close to the ranges but that would not interfere with ongoing range operations.

To select the soil-processing vendor, Battelle conducted an initial review to identify vendors capable of providing the needed services. More than 70 vendors were contacted to request information on capabilities, prior experience, and budgetary cost estimates for a range of services relevant to the planned range maintenance activities. The 25 responses received were screened to identify vendors to receive the performance specification and request for proposal (RFP). Five vendors were selected to receive RFPs, and three responded. Brice Environmental Services Corporation (BESCORP) was the vendor selected.

BESCORP began mobilizing in June 1998 and began shakedown testing at the end of June. Full-scale operations commenced in mid-July and continued until mid-September 1998. The average daily soil-processing rate was 127 cubic yards (190 tons) per day. During the final month of processing, the average daily soil-processing rate was 176 yards (265 tons) per day.

The processed soils were kept in daily stockpiles until analytical data were available to verify that the goal of 5,400 mg/kg was being met. Once the verification data were available, the processed soil was returned to the range for use on the face of impact berms, since everything greater than ¾-inch had been removed from it. The material removed was essentially washed rock and was stockpiled for use by the range.

The average total lead in the unprocessed soil stockpile was 24,700 mg/kg lead, while the average total lead in the processed soil was 1,800 mg/kg, about 1/3 of the goal of 5,400 mg/kg. Therefore, about 93% of the lead in the contaminated soils was removed. In fact, 230 tons of high-purity particulate lead was removed from 11,700 tons of soil. Gravity separation techniques were employed to both separate the lead and concentrate it into a recyclable product that was 90% metal. Because of the very clean condition of the recovered metal, it could be easily recycled. The Base Defense Reutilization and Marketing Office (DRMO) accepted the containerized metal for the purpose of selling the materials and using the proceeds for the base.

The total cost for processing the soils (including the treatability study, mobilization/ demobilization, documentation, soil processing, packaging and managing recovered metals, equipment/pad decontamination, and stockpiling the treated soils) was $66 per ton or $99 per cubic yard.

INFRASTRUCTURE

Cement pads, drainage ditches, and retention ponds were constructed at each of the three ranges prior to installing the bullet traps. The design specification for the concrete in the pads used to support the bullet traps was set at 4,000 pounds per square inch. Concrete pad dimensions for the rifle, pistol, and BZO ranges were 520 × 30 feet, 208 × 30 feet, and 80 × 30 feet, respectively. The concrete pads were 8 inches thick in the front and 12 inches thick in the back to accommodate the design loads.

Concrete pads (8 × 12 feet) were constructed behind the bullet traps to support the dust-control units (DCUs) installed at each range. Two DCU pads were required for the rifle range, while only one was required at both the pistol and BZO ranges.

Permanent electrical power (480 V, 3-phase) was installed at each range to provide power for the DCU systems. The DCUs installed included metal ductwork, blower motors, control circuits, air compressors, particulate filters, and a containment system.

TRAP INSTALLATION

As part of identifying the appropriate pollution system for MCAGCC, Parsons Engineering Science, Inc. of Pasadena, California was subcontracted to perform a screening study to identify and evaluate the available types of bullet-containment systems. Three types of systems were evaluated including friction, deceleration, and impact traps. To select the most appropriate trap, an extensive set of performance criteria were developed, and weighting factors were applied to each trap and for each range. For each of the three ranges, Action Target's Target Total Containment Trap (TCT) scored best. Action Target, Inc., of Provo, Utah was subcontracted to provide and install its TCT at each of the three ranges.

From October to December 1998, Action Target installed a TCT at each of the three ranges. The design specifications included meeting a wind load of 100 mph and a live load of 20 psf. The TCT consists of 3/8-inch-thick sheet steel panels configured in a 3 × 5 or 4 × 4 panel V-shaped configuration. The V-shaped configuration ties into a steel deceleration chamber, where bullets and larger bullet fragments are captured and collected in 5-gallon buckets. The DCU is connected to the deceleration chamber and is designed to collect particulate lead dust. Air discharge permits were required for each of the DCUs.

OPERATION AND MAINTENANCE

A secondary phase of this study was to identify operation and maintenance (O&M) costs associated with the entire pollution prevention system, including the TCT, DCUs, and storm water retention ponds. During a 12-month period starting January 1999, Battelle has procured a local subcontractor (El Adobe Partners, Inc.) to manage O&M activities. After completing one year of O&M, Battelle will provide MCAGCC with an O&M manual for the entire system, including a summary of labor and material costs and recommendations for future O&M.

Installation Restoration at Naval Weapons Station Earle

Remedial Action at Closed Pistol Ranges
Navy and Contractor Personnel—Partnering in Cleanup

Gregory J. Goepfert, P.E.
Environmental Engineer
Naval Weapons Station Earle
Colts Neck, NJ 07722-5014, USA
ph. 908-866-2515, fax 908-866-1166

Michael F. Warminsky
Director of Remediation
Brice Environmental Services Corporation
554 Route 31 - P.O. Box 78
Ringoes, NJ 08551, USA
ph. 908-806-3655, fax 908-806-3655

ABSTRACT

Installation Restoration Sites 24 and 25 were formerly used pistol ranges at Naval Weapons Station Earle. The sites were targeted for cleanup to mitigate the potential for runoff of metals (primarily lead) in surface water and groundwater. The cleanup objective was to remove 90% of the small-caliber projectiles deposited in sandy berms without interfering with mission critical operations. Therefore, the cleanup work required a tight execution schedule and close communication between Navy and contractor personnel.

A cleanup approach maximizing the use of Naval Weapons Earle personnel and equipment in the cleanup process was implemented. The strengths of station personnel and equipment were supplemented with those of Metcalf & Eddy, a contractor accessed via the Navy's Remedial Action Contract (RAC) administered by Northern Division, Naval Facilities Engineering Command.

Initially, dry screening and disposal were evaluated to separate lead from berm soils. However, a treatability study of this method indicated as much as 59 percent of the berm material would be commingled with the lead, making recycling impractical. Subsequent soil-washing feasibility studies indicated more than 95% of the berm material could be recovered for reuse in restoration, while recovering more than 98% of the lead in the berm. Based on these findings, soil washing was selected for implementation.

Over the period September 3, 1996 through October 3, 1996, the cleanup was executed. The station provided not only direct labor to the job, such as heavy equipment operators, truck drivers and hazardous waste handlers, but also support personnel and infrastructure. Additionally, the station's Explosives Ordnance Disposal team was on standby and was consulted when live rounds were found. The station's fire department also issued hot work permits and monitored the job from start to finish. The Navy forces were augmented by construction management personnel, process operators, and field-sampling personnel from Metcalf & Eddy.

INTRODUCTION

The mission of Naval Weapons Station Earle is to receive, store, segregate, and issue ammunition to the U.S. Navy Atlantic Fleet. Past operations included ordnance maintenance activities, such as washout, stripping, painting, and restenciling of mines and torpedoes and demilitarization of ammunition items. Areas of the 12,000-acre station were used for training and for disposal of domestic and industrial wastes. Training areas included the two outdoor pistol ranges, which were closed after approximately 25 years of use. The ranges were cleaned up under the auspices of the Installation Restoration Program at Naval Weapons Station Earle.

OVERVIEW OF REMEDIATION PROGRAM

The Installation Restoration Program at Naval Weapons Station Earle addresses sites where previous activities may have caused, or have the potential to cause, environmental impact. An Initial Assessment Study in 1983 identified 29 such sites. The program will evaluate those sites to identify those that will require remedial action, further study, or no further action. To date, approximately 60% of the sites identified in the 1983 study have been either remediated or determined through further investigations (e.g., soil analysis, groundwater analysis, etc.) to warrant no further action. The two closed pistol ranges addressed by this paper were identified as Sites 24 and 25 under the Installation Restoration Program.

As a consequence of the use of Sites 24 and 25 as pistol ranges, a significant number of small-caliber bullets and empty casings were deposited in the sandy berms and in the firing line areas. The primary contaminant of concern was lead, as the ranges were to be closed and converted into multiuse recreation areas. In accordance with the U.S. Environmental Protection Agency (USEPA) and the New Jersey Department of Environmental Protection, a minimum of 90% of the projectiles would be removed, with the soil cleanup goal for total lead not to exceed 400 mg/kg.

A removal action was selected as the most appropriate method to meet cleanup goals because this alternative would serve to minimize the potential for runoff of metals in surface water and groundwater from the sites and reduce the potential of people coming in contact with the contaminants after range closure. The removal action was consistent with Navy policy to close existing small arms ranges that are no longer necessary to support mission requirements in a manner that is protective of human health and the environment.

SCHEDULING CONSTRAINTS

One of the logistical challenges of this project was to ensure the availability of equipment and personnel for ship loading/off-loading operations; this project had to be scheduled such that those mission critical operations could be adequately supported. Therefore, phasing of labor and equipment for mobilization, project execution, and demobilization required close attention to the demands of port operations. The tight scheduling constraints required solid planning on the part of management personnel. This aspect of the project demonstrated command commitment and teamwork to bringing this task to successful completion, and station personnel and equipment were positioned at the sites when needed. The entire project was completed in about one month.

FEASIBILITY STUDY

Prior to mobilization, a feasibility study[1] was conducted on a five-gallon sample of soil from each range to evaluate three removal alternatives: nonhazardous direct disposal, screening/ recycling, and soil washing/recycling. Of the three, it was originally anticipated that the direct disposal option could be the most cost-effective. However, initial assessment of the berm soils showed the total lead levels to range from 19,346 mg/kg to 38,529 mg/kg. In addition, the corresponding TCLP lead levels exceeded the 5 mg/L RCRA level; therefore, all of the berm material had to be classified as "characteristically hazardous" and disposed of as hazardous waste. In addition to the higher cost of this option was the never-ending long-term liability associated with hazardous waste disposal.

The second option evaluated was screening/recycling. Since the samples consisted of a well-graded sand with the bulk of the lead present in the form of particulates larger than ¼ inch, it seemed logical that passing the berm soils over a ¼-inch "dry screen" would remove the larger than ¼-inch lead in a form suitable for recycling, while rendering the balance of the soil suitable for reuse. To evaluate this option in the lab, the soil was screened into nine size fractions, with total lead analysis conducted on each fraction. Elevated lead levels were found not only in the larger than ¼-inch material, but also in material down to 28-mesh sand particles and clays finer than 150-mesh. As such, the screening option would have required removal of all material larger than 28-mesh and all material smaller than 150-mesh, which represented 59% of all material at the site. While the lead content of this material was in percent concentrations, it was not high enough to recover any salvage value; and in fact, recycling this material would have required payment similar to that for hazardous waste disposal. The recycling option, however, does break the cradle-to-grave chain of responsibility associated with disposal.

To further reduce the amount of material going off site, soil washing, a water-based process combining both physical and gravity separation, was also evaluated. As with the screening option, the soil was first screened into nine size fractions. Those fractions with lead levels above the cleanup goals then under went a subsequent gravity separation step, further separating the lead fragments from similar-sized sand/stone particles. This process resulted in recovery of more than 99% of all lead present, with more than 95% of the berm material meeting the cleanup goal and suitable for reuse. As such, this option could save more than $134,000 over either of the other two options, and it was selected for implementation.

While the feasibility study was being conducted, Navy personnel were preparing the site and stockpiling impacted materials. These concurrent activities shortened an already tight project schedule by more than a week and allowed for implementing field activities without delay after the remedy was selected.

PROJECT TEAM

This project was made unique by joining the process expertise of Metcalf & Eddy, subcontracted by the Navy's Remedial Action Contractor, Foster Wheeler, with the manpower, equipment, and support infrastructure of Naval Weapons Station Earle. In this era of fiscal austerity, the partnership established on this project team enabled a substantial savings to be realized in contrast to the conventional turnkey remediation contract.

The use of heavy earthmoving equipment located on station reduced the mobilization cost and demurrage charges; use of station-qualified personnel to operate equipment assured an accessible workforce for the job, reducing the need to pay for travel expenses for equipment operators and laborers. Maintenance mechanics were available to repair hydraulic equipment in the event of failure. Nonhazardous process water (6500 gallons) was disposed of at the station's wastewater treatment plant. Additional support to the job was provided by the station fire department to ensure effective oversight of the job from a safety perspective. The station's Explosives Ordnance Disposal Unit was also available to respond in the event of the discovery of unfired rounds. A Navy industrial hygienist monitored the workers for lead exposure on site; he also conducted the required Site Safety and Health briefings.

SOIL PROCESSING

The objectives of the project were to remove at least 90%of the lead in the berm, with soils containing less than 400 mg/kg total lead deemed suitable for reuse. To expedite field activities and minimize material handling, the process equipment was set up at the larger of the two ranges. It was staged on a polyethylene liner and configured to mimic the process proven effective during the feasibility study. Processing water was recycled in a closed loop, with makeup water obtained from a nearby fire hydrant.

Approximately 85%–90% of the metal bullets were found to be located between the surface soil and as much as 18 inches below ground surface. Careful excavation and close coordination between Navy personnel and the contractors' sample technicians performing postexcavation sampling resulted in "surgical" removal of contaminated material, resulting in a 500-ton reduction of material requiring treatment versus the original anticipated volume.

The soil-washing system provided three output streams: concentrated lead (bullets), washed sand, and fine clays. The washed sands were conveyed to a Navy dump truck and staged on plastic to await post-treatment confirmation samples. The fine clays collected were also sampled for reuse criteria, and the bullets were collected in drums for subsequent recycling. In accordance with USEPA and the New Jersey Department of Environmental Protection, soils had to test below 400 mg/kg lead to be reused on site. The recovered bullets were sold to a recycler for scrap value, with the proceeds used to fund subsequent quality of life projects at the base. The clays were either reused (less than 400 mg/kg total lead) or solidified and recycled at a local asphalt plant (more than 400 mg/kg total lead).

PARTNERING

Call it partnering, teamwork, or cooperation, this remediation project was a reflection of what a dedicated group of Navy, contractor, regulatory personnel, and concerned citizens can accomplish working together toward a clear goal. The willingness to attempt an unconventional project collaboration, but one that made sense from the perspectives of technical merit and cost, contributed to drive this project to success.

Naval Weapons Station Earle, in consonance with the Policy of the Chief of Naval Operations (CNO), had established a Restoration Advisory Board (RAB) of concerned local citizens that supported the need for and the approach of this project before it was undertaken. This project also proved that partnering with the community is an essential ingredient to effective execution.

Subsequent to a RAB meeting of November 14, 1996, the *Asbury Park Press* published a very positive article on November 15, 1996 entitled “10 Tons of Bullets Cleaned Up at Earle.” Additionally, USEPA stated in its August 9, 1996 letter, “we are very supportive of the Navy’s efforts through this removal action to address environmental concerns at NWS Earle.” In reference to the pistol range cleanups, USEPA offered that, “Excellent coordination with your contractor (Metcalf & Eddy) and Navy Northern Division [Naval Facilities Engineering Command] and good communication with USEPA and NJDEP helped ensure a quick, efficient and professional operation.”

The Navy’s Remedial Action Contractor, Foster Wheeler, also realized the advantage of subcontracting with Metcalf & Eddy, who delivered key personnel, equipment, and technology in a timely manner. Notwithstanding, Foster Wheeler played a major role in the disposal of process residuals and in managing tight schedule constraints.

CONCLUSIONS

The objectives were met. Approximately 1500 tons of soils was processed, and 10 tons of bullets was recovered and recycled. About 70 tons of clay fines required recycling at an asphalt batch plant. The remainder of processed soils met the criteria and were reused on the sites, with residual total levels ranging from 14.6 mg/kg to 92.2 mg/kg.[2] The combination of proven, commercially available soil-washing equipment, an existing contract, and a “can-do” project team enabled the successful completion of the project within the schedule constraints and without disrupting mission-critical operations. The benefits of partnering afforded all concerned the opportunity to achieve a successful remediation effort. With all of the above considered, the tangible benefit of this Navy-contractor team yielded a project cost savings of approximately 30% over more traditional approaches.

REFERENCES

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Stabilization Case Studies

Twin Cities Army Ammunition Plant, Arden Hills, Minnesota

BACKGROUND

The former Twin Cities Army Ammunition Plant (TCAAP) is a 4-square-mile site located in New Brighton/Arden Hills, Minnesota. The extent of contamination covers a 25-square-mile area. Land use in the area consists of residential, commercial, and industrial with on-site wetlands and woodlands surrounding the Rice Creek watershed. From 1941 to 1981, the site was used to manufacture, store, and test small arms ammunition and related equipment. Waste materials such as VOCs, heavy metals, corrosive materials, and explosives were disposed at 14 source areas. Several of the source areas impacted by test firing activities were targeted for remediation to remove metals and reduce the toxicity characteristic concentrations of the soil.

REMEDIAL OBJECTIVES

The remedial objective for this work included on-site stabilization of contaminated soil to below the Toxicity Characteristic (TC) criteria for lead and antimony and off-site disposal.

SELECTION OF TECHNOLOGY

Phytoremediation and lead-extraction processes were implemented in earlier remediation phases of the TCAAP project. In 1998, EnviroBlend® was selected in a competitive bid process to stabilize additional soil. Total lead concentrations in the soil were between 113,000 and 330,000 mg/kg. Stabilization with EnviroBlend® achieved results below the TC criteria of 5.0 mg/L for lead in the Toxicity Characteristic Leaching Procedure (TCLP) test.

IMPLEMENTATION OF TECHNOLOGY

Contaminated soil at the TCAAP site was characterized, excavated, and stockpiled. A coarse granular EnviroBlend® was thoroughly mixed in the stockpiles using conventional construction equipment at a recommended dosage rate of 3%. The EnviroBlend® stabilization process does not require the use of water or a curing period. The treated material was then analyzed using the TCLP test. All stabilized material passed the TC criteria and was disposed in a Subtitle D landfill.

Ethylene diamine tetra acetic (EDTA) acid was found in soil at a portion of the site, potentially left over from former lead-extraction processes implemented at the site. EDTA complexes lead and other heavy metals and increases their leachability. Through a quick-turnaround treatability study in RMT's applied chemistry laboratory, RMT demonstrated treatment effectiveness using EnviroBlend® on a representative sample of soil contaminated with lead and EDTA.

COSTS

EnviroBlend® was used for the stabilization of 47,000 tons of soil. The total project cost was $777,000 for soil stabilization assistance, including treatability studies, technical assistance, pilot studies, and reagent supply.

POINT OF CONTACT

Ken Christenson
U.S. Army Corps of Engineers
(402) 221-7828

Cedar Rapids Firing Range, Cedar Rapids, Iowa

BACKGROUND

The site is an active firing range in Cedar Rapids, Iowa for police officer training. The backstop berm area was reconstructed to address environmental concerns with high-lead concentrations in the soil and to provide additional protection for neighboring properties.

REMEDIAL OBJECTIVES

The remedial objectives at this site were to stabilize the lead-impacted soil to meet the Toxicity Characteristic (TC) criteria for lead, recycle lead bullets, and restore the berm for future use.

IMPLEMENTATION OF TECHNOLOGY

Soil Stabilization
Prior to screening lead from the berm soil at the gun range, soil was stabilized using EnviroBlend®, a dry, coarse chemical delivered to the site in dump trucks. EnviroBlend® was applied surficially to site areas requiring treatment, then mechanically blended into the soil using a tracked excavator. The soil was blended until a homogenous mixture was achieved. *In situ* treatment of the soil prior to excavation allowed the material to be rendered nonhazardous prior to further management, avoiding generation of an unpermitted hazardous waste pile. Following treatment of the soil, two samples were collected for Toxicity Characteristic Leaching Procedure (TCLP) -lead analysis. The TCLP results demonstrated lead concentrations below 5 mg/L in the stabilized material.

Lead Screening
After the soil was treated and confirmed to be nonhazardous, RMT screened lead bullets from the soil using a MKII PowerScreen with a 3-inch upper deck and a ¼-inch lower deck. Soil was fed into the hopper on the screen, and three material piles were generated:

1. Material retained on the 3-inch screen—typically large soil clods, debris, and rocks.
2. Material retained on the ¼-inch screen—expected to be lead material.
3. Material passing through both screens—fine soil particles.

Lead Management
Lead recovered from the soil was to be transported to the Doe Run Resource Recovery Facility in Boss, Missouri for recycling. Analysis of the lead-containing material screened from the soil indicated it was approximately 50% lead by weight and not suitable for recycling. EnviroBlend® stabilizes soil, and the treated material is stable over a wide range of conditions and is protective of leaching to groundwater. Because of this quality, the screened and stabilized material could be used as backfill for reconstructing the core of the backstop berm.

COSTS

The total project cost for EnviroBlend® stabilization and screening was $45,000.

POINT OF CONTACT

Dwight Dholman, City Engineer
City of Cedar Rapids
(319) 286-5809

Nahant Marsh, Davenport, Iowa

BACKGROUND

The Nahant Marsh site in Davenport, Iowa is a former shooting range with lead-contaminated soil and sediment. Heavy-metal contamination consisting of lead, arsenic, silver, and antimony was found in soil and sediment surrounding the five shooting platforms on site. An additional shooting area was identified that appeared to have been used early in the history of the site. An estimated 9 tons of lead shot was deposited on the site annually for 27 years for a total of 243 tons of lead shot.

The source area was identified as the area impacted by past shooting activities. The U.S. Fish and Wildlife Service conducted sampling of the marsh area and found up to 283 lead pellets per grab sample in sediment samples collected between 109 and 177 yards from the shooting platforms. Local waterfowl were diagnosed with lead poisoning from lead shot. Since arsenic, silver, and antimony concentrations did not exceed RCRA Toxicity Characteristic Leaching Procedure (TCLP) limits, lead was the only constituent of concern.

REMEDIAL OBJECTIVES

The remedial objectives for this site included development and implementation of a stabilization approach to meet the Toxicity Characteristic (TC) criteria of 5.0 mg/L for lead in the TCLP test, followed by off-site disposal of stabilized material.

IMPLEMENTATION OF TECHNOLOGY

Through bench-scale treatability study analysis, RMT determined a 2% dose of EnviroBlend® would effectively reduce TCLP-lead concentrations in the soil to below 5.0 mg/L. EnviroBlend® was applied to stockpiled material, then thoroughly mixed using conventional construction equipment. After receiving confirmational results from a certified laboratory, the stabilized material was disposed of at an off-site landfill.

COSTS

The total project cost for EnviroBlend® stabilization was $52,000 for 7,700 tons.

POINT OF CONTACT

Don Lininger
Subcontractor for USEPA Region 7
(913) 551-7724

Beneficial Uses for Recycling of Organic and Inorganic Contaminated Soil with Encapco's $_2$RM™ Process

INTRODUCTION

In many areas where aggregate materials are not locally available and must be imported, the cost savings from recycling contaminated soils that would otherwise not be useable can be substantial. Recycling of contaminated soils can reduce the time that land remains nonproductive until site remediation can restore it to a beneficial use. In the United States, large quantities of soil on deactivated military bases and industrial properties must be remediated before site closure is possible. Encapco's $_2$RM™ technology can provide a time-saving solution to these problems.

Since early 1994, federal and state of California agencies have completed two projects that evaluated the effectiveness of contaminated soil remediation using a cold-mixed asphalt emulsion technology. These studies were conducted at a military facility and state highway project in northern California for the U.S. Army Corps of Engineers and the California State Department of Transportation (Caltrans). Last year, the U.S. Environmental Protection Agency (USEPA) and the Civil Engineering Research Foundation (CERF) of the American Society of Civil Engineers established an Environmental Technology Verification (ETV) Center. The ETV Center will conduct pilot studies to verify the performance of new, commercial-ready environmental technologies and transfer this information to users, such as trade and consulting engineering organizations. Encapco's use of organic emulsions to chemically encapsulate soil contaminated with inorganics such as lead was selected as one of the first pilot programs under the ETV program.

OBJECTIVES

Recent asphalt stabilization pilot studies have demonstrated that an environmental liability can be transformed into an asset and a useable end product that meets regulatory requirements as a comparative cost savings over alternative treatment and disposal methods. These technology projects developed contaminated soils remediation data that

- Demonstrated the feasibility of transforming a hazardous waste to a nonhazardous construction material that meets conventional engineering design and materials standards for roadway bases, light traffic pavements, landfill caps, berms, and levees, while mitigating a concern over the fate of encapsulated contaminants.
- Addressed regulatory compliance requirements, including demonstration of the effectiveness of encapsulation of contaminants in the emulsified asphalt matrix by certified test results.
- Provided a practical, cost-effective substitution for a commercial roadway construction product that meets industry standards.
- Provided owner-users, developers, and governmental agencies with an acceptable project alternative to other soil remediation options with the added benefit of a reusable product.

GENERAL CONSIDERATIONS

There is a wide range of technologies that are applicable to the remediation of contaminated soil. An approach developed in the United States to help project site cleanup managers identify parameters for evaluating the suitability of alternative technologies is a matrix called “Treatment Technologies Applications Matrix for Base Closure Activities.” (Ref. 1) This matrix was prepared to help in efforts to accelerate restoration and reuse of closing military bases throughout the state of California. It emphasizes that determining the best technology requires careful evaluation of several, mostly site-specific, considerations.

Unless the type and degree of contamination is known, it is difficult to choose the most suitable technology. It is very costly to fully characterize an unknown waste, so it is important to identify both the compounds of concern and the compounds suspected of being in the soil. Soil characteristics can also have a limiting effect on many processes. The most common problem is the ineffectiveness of many in-situ processes on clay formations due to their imperviousness to vapor and liquid flow.

The volume of soil to be treated influences the cost of selected processes because of economies of scale. The depth below ground surface of the contaminant must also be considered because of the costs of deep excavations to reach lower contaminated zones. The length of time it takes to reduce contaminant concentrations below target levels and restore a site to productive use often becomes a cost that many site owners cannot afford. Technologies that speed up the remediation cycle will often be more desirable than slower processes.

Some remediation processes produce emissions or other side effects that are undesirable or prohibited by local governments or the public. For example, high temperature oxidation (incinerators) or thermal desorption can be very effective in destroying organic materials but be politically unacceptable.

Because the end product of this technology is typically a roadway pavement base, or fill material placed on or in the land, the relevant environmental rules and regulations in the United States come under USEPA and State of California Department of Toxic Substances Control (DTSC) regulations for materials classified for “use in a manner constituting disposal.” USEPA has issued regulations that exempt recycled waste from Resource Conservation and Recovery Act (RCRA) regulations, provided the following conditions apply:

- The resulting product is produced for the general public’s use.
- The product contains recyclable materials that have undergone a chemical reaction as to become inseparable by physical means.
- The product meets the Land Disposal Restriction (LDR) standards.

Most states administer the RCRA program within their jurisdictions without any modifications. The state of California has adopted regulations that exempt such materials under the same conditions as USEPA, except that the recycled waste products must be derived from non-RCRA hazardous wastes and meet specific criteria for toxicity and leachability after mixing and encapsulation.

Under Article 3, Section 66366.30, Chapter 16, Division 4.5 of Title 22, California Code of Regulations (CCR), contaminated soils that may be used in the production of asphalt pavement or asphalt-treated road base are considered recyclable materials that are placed on the land. Under specified conditions, these recycled products can be excluded from classification as a waste. Included in these conditions is the requirement that hazardous constituents in the recyclable material whose concentrations are greater than or equal to the Soluble Threshold Limit Concentrations (STLC) set forth in Section 66261.24 (a)(2)(A) of Title 22 CCR shall be chemically reacted or become physically bound so as not to leach from the product containing the recyclable material.

ASPHALT EMULSION TECHNOLOGY

Site remediation treatment technologies generally fall under the following categories: biological treatment, chemical treatment, physical separation, stabilization, and thermal treatment. Asphalt stabilization has some fundamental differences from the most commonly used cement or pozzolonic-based stabilization processes. Pozzolonic materials consist of lime and other silicates, which are high-pH inorganics. In contrast, emulsified asphalt is an organic material with a more neutral pH. Asphalt stabilization has been used to remediate relatively large volumes of soil (more than 3,000 cubic yards), contaminated with heavy petroleum hydrocarbons (e.g., diesel, crude oil, or motor oil) or with some metals (e.g., copper, lead, and zinc). Contaminated soil is mechanically crushed and/or screened to yield a graded aggregate that is mixed with asphalt, resulting in an asphalt paving mixture. The contaminants are stabilized by the $_2$RM™ process, that is, chemically and physically fixated by the asphalt to reduce leaching.

The use of emulsified asphalt in paving goes back some 50 years. The first commercial asphaltic emulsions for paving were emulsified-asphaltic oils for dust-laying. In order to be used for a paving material, asphalt concrete or asphalt-treated bases must be strong enough not to shove, flow, or rut under traffic loading, yet be resilient enough not to crack, chip, or break apart under the same loads through weather extremes of heat, cold, water, snow, or ice. Guidelines have been developed and published for the use of asphalt emulsions to create road-base materials. The Asphalt Institute Manual series (Ref. 2) publishes specifications and methods for emulsified-treated base.

Asphalt emulsions consist of intimate mixtures of asphalt, water, and an emulsifying agent. The physical and chemical properties of the emulsion depend on the emulsifying agent's chemical type and molecular structure. When the emulsifying agent is mixed with asphalt and water, its molecules align with those of the asphalt and water, forming an emulsion with a negative (anionic) or positive (carbonic) surface charge. The presence of charged chemicals in emulsions improves the adhesion of asphalt to aggregates over the adhesion that occurs in asphalt concrete. The surface of aggregates carry a charge; and if this charge is opposite that of the emulsion, a stronger bonding can take place.

The objective is to make a dispersion of the asphalt emulsion in water, stable enough for pumping, prolonged storage, transportation, and mixing. During mixing, the emulsion coalesces and encapsulates the soil particles. The hydrocarbons in the soil preferentially adsorb onto the asphalt surface and diffuse into the asphalt. The result is a blending of the contaminant with the asphalt into an integral, stable part of the mixture that is chemical bonded. Upon curing, the emplaced $_2$RM™ product retains the adhesive, durability, and water-resistant properties of the asphalt cement from which it was produced, provided the emulsion mix was properly designed.

The $_2$RM™ product meets the Caltrans design specifications for aggregate road base or sub-base for highway construction projects. Test cases have shown that the product is stronger than a typical aggregate base course and can have characteristics of higher-grade construction materials as well. It reaches full hardness in approximately 30 days and can be used as a substitute for standard Caltrans Class 2 or 3 aggregate base rock.

The potential for encapsulating heavy metals using a proprietary organic emulsion process that is comparable with asphaltic emulsions has been studied and found to be feasible under certain conditions. The technology used to solve contamination problems while creating a useful product utilizes specialty emulsions designed for total petroleum hydrocarbons (TPH), heavy metals (primarily lead), and PAHs. Because of the organic chemistry used in the technology, the assimilation of TPH and PAHs into the cured product is an expected result, based on the principle of “like dissolves like.”

PROJECT PLANNING AND CONSTRUCTION OPERATIONS

The remediation projects were conducted by Encapco in cooperation with federal and state of California agencies. The projects included evaluation of site-specific soil conditions, laboratory treatability (bench-scale) testing, and field pilot studies to determine feasibility. The projects consist of three basic stages:

Site-specific Mix Design – Site samples are taken to a testing laboratory for

- chemical/toxicity analysis for contaminant encapsulation,
- structural analysis for engineering design purposes, and
- formulation of mix design to satisfy environmental criteria and construction industry specifications.

On-site (ex-situ) Mixing (for micro or chemical fixation) – Excavated soil is stockpiled and prepared for

- screening to remove deleterious material,
- feeding to a rotary pug mill,
- addition of emulsion and mixing with soil, and
- delivery of mixed $_2$RM™ product in trucks to placement location.

Placement (macro encapsulation) – The product is placed using conventional construction techniques:

- road preparation and grading,
- placement and compacting, and
- curing.

OBSERVATIONS AND RESULTS

Two demonstration projects were performed in the state of California. Fort Hunter Liggett (FHL) treatability studies for the U.S. Army Corps of Engineers, and Interstate 80 Highway Corridor in Emeryville and Richmond for Caltrans (Ref. 3). The Fort Hunter Liggett study was previously reported in a paper presented to the Air Force Center of Environmental Excellence Conference in San Antonio, Texas in August 1995 (Ref. 4).

Fort Hunter Liggett Pilot Treatability Study

Laboratory testing for the FHL pilot study was started in August 1994, and fieldwork was completed in September 1994. Approximately 780 tons of contaminated soil was made available for the study. Prior to the start of the pilot study, a site investigation was completed to collect soil characteristics data. The maximum concentration of TPH as motor oil in the soil samples was 8,000 milligrams per kilogram (mg/kg). In order to start with a concentration of 15,000 mg/kg, the soil samples were "spiked" with motor oil. Two months prior to the field study, Encapco performed laboratory bench-scale testing on samples collected from the stockpiled contaminated soil and formulated a site-specific emulsion mix design. Bench-scale analytical test results are shown in Table 1.

Table 1. Bench-Scale ETB Product Samples Test Results

ENGINEERING PROPERTIES		ANALYTICAL		
R Value	18@17% emulsion	Tests	Requirement	Result
Flow, 0.01 in.	10.6 – 11.7	TCLP Extraction		
Expansion pressure (300 psi)	380	Volatile Organics	EPA 8240	ND
Marshall Stability, lb.	520 – 722	Semivolatile Organics	EPA 8270	ND<100 ug/l
% Bitumen by dwa	12.16 – 13.44	STLC – Metals		
% Emulsion by dwa	19.0 – 21.0	Lead, mg/l	5.0	ND<0.5
		Cadmium, mg/l	1.0	0.1

On-site mixing was based on a maximum aggregate size of 1 inch because of pug mill auger capacity limitations. A portable screening unit was set up to screen out materials greater than 1 inch. All premixing operations were performed within a delineated exclusion zone in accordance with proper hazardous waste operation procedures. This included stockpiling, screening, pug mill hopper, conveyor, and mixer equipment.

The screened soil was processed with the designed emulsion over a two-day production period. On average, the pug mill produced approximately 75 tons of soil/asphalt emulsion mixed product per hour. This production rate was considered relatively low because of the special steps taken to calibrate the digital belt scale to maintain asphalt emulsion loading rates between 17 percent and 22 percent by dry weight aggregate (dwa). A number of improvements were identified that could effectively raise hourly production to a minimum of 300 tons per hour, while maintaining the same daily quality control.

The product produced from the pug mill was transported by dump trucks to a dirt roadway and recreational vehicle parking area located approximately six miles away. The product was placed by conventional road grading means as a substitute for Class 2 aggregate base rock. A double chip seal surfacing was applied over the product to function as a wearing surface. Core samples of the final roadway section were taken and analyzed for the leachability potential of hydrocarbons in the $_2$RM™ product. A summary of the core samples test result is shown in Table 2.

Table 2. ETB Core Samples Analytical Results

ENGINEERING PROPERTIES		ANALYTICAL		
Flow, 0.01 in.	10.5 – 12	Tests	Requirement	Results
Marshall Stability, lb.	748 – 1045	TCLP Extraction		
% Bitumen by dwa	12.21 –13.94	Volatile Organics	EPA 8240	ND
% Emulsion by dwa	19.1 – 21.8	Semivolatile Organics	EPA 8270	ND
		STLC – Metals		
		Lead, mg/l	5.0	ND<0.25
		Cadmium, mg/l	1.0	0.060
		Zinc, mg/l	250	ND<10

Interstate 80 Highway Field Project

The Caltrans project was conducted between two sites along the Interstate 80/580 Corridor east of San Francisco Bay. The first project site involved widening roadway sections and constructing connector ramps along Route 580 to northbound Interstate 80 in Emeryville. The second project site involved an interchange at Richmond Parkway and I-80, roadway sections, and a commuter "park and ride" lot.

Approximately 11,000 tons of contaminated soil was removed from a former steel mill site in Emeryville. The soils contained lead concentrations of up to 2,3000 mg/kg. Analytical tests characterized the soil as a "California-only" hazardous waste but below the federal limit for a RCRA characteristic waste. According to Waste Extraction Test (WET) results, leachable lead concentrations were as high as 17 mg/l. However, Toxicity Characteristic Leaching Procedure (TCLP) results were below the federal limit of 5 mg/l. A representative set of samples was taken from the site and evaluated for chemical and engineering structural characteristics. Strict testing protocols were followed to ensure thorough characterization of the material and to provide accurate data for the asphalt emulsion mix design. A summary of the Emeryville site soil characteristics prior to treatment is shown in Table 3.

Table 3. Caltrans Project Soil Characteristics Prior to Treatment

STRUCTURAL CHARACTERISTICS		ANALYTICAL		
Sieve Size	% Passing	Tests	Composite	Lot 4
1 inch	100	TCLP Lead, mg/kg	1,800	2,300
#4	59.1	STLC Lead, mg/l	20	335
#200	12.9	TPH, mg/kg	110	160
Sand Equivalent	32			
Plasticity Index	N/P			
Maximum Density	142.2@7.6%			

Bench-scale evaluation and testing led to an emulsion design capable of physically encapsulating the lead contamination while creating a high-quality road base product. The resulting mix design was applied to the stockpiled soil at the Richmond site using a conventional pug mill. Test pellets were prepared and bench-scale tested to verify that performance criteria were met or exceeded.

The on-site mixing stage involved excavation and stockpiling of the contaminated soil at the Emeryville site. The soil was screened to a sieve size of 1 inch or less, then mixed by weight and moisture conditioned as required. No additional aggregate was added during the process. The soil was hauled to the Richmond site and stockpiled. At the Richmond site, the asphalt emulsion was proportioned by batch weight and mixed with the soil in a pug mill. The quantity of water was adjusted to meet optimum moisture content requirements.

Quality control sampling and testing were used throughout the process to verify field performance. Following completion of the production phase, core-drilled samples of the in-place product were taken to verify performance. Testing protocol included chemical analysis and structural integrity testing for residual asphalt binder within the mixture, Marshall Stability, flow, softening point, and penetration. A summary of the postproduction product characteristics is shown in Table 4.

Table 4. ETB Postproduction Characteristics

STRUCTURAL INTEGRITY		ANALYTICAL				
Test	Result	Tests	1	2	3	4
Cohesion Value	769	STLC Lead, mg/l	.45	.33	ND	ND
Moisture/Density	131 lb. @ 10.8% moisture	TPH	N/A	N/A	N/A	N/A
R-Value (cured)	95					
Marshall Stability	@ 15% 2617					

The structural strength of the product was further verified by the use of field deflection measurements on a section of roadbed. A preliminary evaluation of the Caltrans Gravel Factor equivalent was made by Dynaflect deflection measurements and AASHTO structural evaluation calculations. These tests resulted in a Gravel Factor of 1.5, which is slightly higher than assumed for asphalt-treated permeable base (1.4) but significantly higher than Class 2 aggregate base (1.1).

BENEFITS

The Fort Hunter Liggett and Caltrans projects demonstrated the commercial viability of the $_2$RM™ process from the standpoint of remediating hazardous materials and recycling the treated materials into an economical construction material that would otherwise not be available. In addition, the projects demonstrated the resolution of an expensive environmental problem of disposal of the contaminated soil.

Some benefits of ETB realized on both projects were the following:

- Successful elimination of the hazardous waste generator liability by transforming it into a commercial construction product at an economical cost.
- Application of ETB emulsion and contaminated soils without the need for additional aggregate material.
- Achievement of structural strengths for roadway base courses, above those required by Caltrans specifications.
- Production of an emulsion that is highly effective in encapsulating TPH and soluble lead.
- Provision of a cost-effective solution to waste management problems for owners and operators of a wide variety of facilities with heavy petroleum and metal-contaminated soils.

NEW DEVELOPMENTS WITH OTHER ORGANIC EMULSIONS

Other organic emulsions have been developed recently for use in recycling of metal-bearing RCRA-contaminated soils. These new emulsions are compatible with the asphalt emulsions used on the Fort Hunter Liggett and Caltrans projects but are capable of chemically encapsulating heavy metals. Soil characterized as “yellowish-brown clayey sand with gravel/sandstone” was used in an on-going laboratory testing program conducted by Encapco to provide guidelines for the innovative emulsions. The soil contained approximately 30 percent silt or clay and had an optimum moisture content of 11.4 percent. Lead sulfate was added to the soil as a dry powder at a concentration of 2,000 mg lead per kilogram. This would typically result in about 55 mg/l when the spiked soil was tested under the TCLP. USEPA regulations classifies a waste as hazardous if its TCLP is 5 mg/l or greater.

Two emulsion formulas using both asphalt and tall oil pitch as a base have been successful in chemically fixing lead in the spiked soil in recent laboratory tests. A typical emulsion formula consists of about 50 percent organic base material, emulsifier, and additives. The remaining 50 percent is water. A dosage of 8 percent by weight, a material suitable for $_2$RM™ construction, has been produced, which reduced the soluble lead from 55 mg/l to below 5 mg/l when tested by the TCLP.

These emulsions are readily produced using conventional equipment and techniques and have shown good stability and handling properties. Test data indicate that scaling up to the field-mixing stage with these improved emulsions should not present any significant problems. Field-scale performance of these organic emulsions will be the focus of Encapco's planned pilot studies with the Civil Engineering Research Foundation's Environmental Technology Verification program.

CONCLUSIONS

With the current focus on waste reduction by recycling, cold-mix asphalt stabilization technology provides a viable, cost-effective alternative to other on-site soil remediation technologies. The $_{2}$RM™ product provides a practical solution to the environmental problems of contaminated soil and provides a direct benefit to agencies and owners who have projects involving roadways, landfill caps, berms, levees, and other similar facilities.

Data from the projects described in this paper show that the chemical and engineering properties of the end product can be managed as a nonhazardous, nonregulated construction material. Upcoming USEPA/CERF ETV pilot studies of organic emulsions designed to chemically fix heavy metals and other semivolatile organics will produce more data to confirm the feasibility of exempting recyclable contaminated soils that fall under the regulatory definition of "use constituting disposal." In short, this technology offers a cost-effective and timely answer to the waste management concerns of owners and developers of a broad range of sites with contaminated soils problems.

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APPENDIX B

Mining-Based Sampling Overview

Courtesy of
Brice Environmental Services Corporation

Mining-Based Sampling Overview

Field sampling of small arms ranges poses many challenges that render conventional sampling methods insufficient for range soils with particulate contaminants. Not recognizing the unique features of small arms firing range contamination and applying conventional sampling and analytical techniques will result in widely varying data, making interpretations difficult as outlined in the following examples.

Example #1

Consider the following:

- A 1.0-lb (454 g) sandy-soil sample that contains 20 pieces of small particulate lead (0.07 g each or 1.4 total g of lead), and there is no other lead contamination in the soil.
- The 1.0-lb sample contains 3,084 mg/kg total lead (1.4 g/454 g = 0.308% or 3,084 mg/kg)

Now let's suppose that an analyst weighs out triplicate 2-g subsamples for total lead analysis following the standard USEPA method:
Sample #1: Consider that there was 1 piece of lead in the sample. If the lead completely digested, the analytical result would be 0.07/2 g = 3.5% lead or 35,000-mg/kg Pb.

Sample #2: Consider that this time that there was no particulate lead in the sample. The analytical result would be 0.0-mg/kg total lead.

Sample #3: Consider that there are 2 pieces of lead in this sample (statistically unlikely but not beyond the level of probability). The analytical result would be 0.14/2 g = 7% lead or 70,000-mg/kg total lead.

Essentially, the true total lead content of the sample (3,084 mg/kg) cannot be determined following USEPA methods. Either a value of 0.0 mg/kg will be generated or a value much higher than the true value. If the particulate lead is not removed first, the only way that the true total lead value for the sample can be determined is if the complete 1-lb sample were analyzed (a total of 227 2-g samples) and the results averaged.

The solution is to employ both mining-based methods and USEPA methods. The particulate lead should be removed using density separation techniques, followed by triplicate digestion and analysis of the particulate lead-free soil. The mass of recovered particulate lead (mg/kg) can then be added to the average soil total lead result (mg/kg) for a more accurate accounting of the total lead in the soil.

Example #2

The distribution of nonparticulate lead contamination in the soils of small arms firing ranges is a function of soil particle size, with the highest total lead residing in the finer soil fractions. Table 1 contains residual lead concentrations for soil collected from Range 13 at Fort McClellan during a range assessment project and illustrates the distribution of lead as a function of decreasing particle size.

Individual granules of the soil can be significant relative to the size of a subsample taken for analysis, so the analytical results can vary depending on the particular group of granules selected in the subsample. As shown below, the minus 50-mesh soil fraction comprises 61% of the soil yet contains over 97% of the nonparticulate lead in the soil. The minus 200-mesh soil fraction alone makes up only 34% of the soil gradation yet contains over 72% of the nonparticulate lead in the soil. Note also that there is more than an 18-fold difference in total lead between the 4 x 10 fraction and the minus 200-mesh fraction.

Typically, the coarse soil fraction (plus ¼ inch) is not included in the 2-g sample taken for digestion and total lead analysis (given the 2-g sample size typically used for digestion, only fine soil fractions can be used). With no controls governing the granule size and number of granules selected for digestion, each 2-g sample will contain a different soil gradation. Consequently, for example, one sample that contains more minus 200-mesh soil portions will generate a higher total lead result than a sample containing more 10 x 50 soil.

Table 1. Residual Lead Concentrations for Soil Collected from Range 13 at Fort McClellan

Soil Gradation **(Standard Sieve Mesh Size)**	**Soil Gradation** **(%)**	**Residual Lead Concentration by AA (mg/kg)**	**Residual Lead Distribution** **(%)**
+3/8"	18.85	10	0.20
-+4	4.53	50	0.24
-4 x 10	3.65	108	0.43
-10 x +50	11.25	165	2.00
-50 x +200	27.80	836	25.06
-200	33.92	1,970	72.07
Treated Soil Totals	100%	927	100%

The complete soil contains an actual weight-averaged total lead value of 927 mg/kg. In order for this value to be derived from the standard 2-g soil sample, digested, and analyzed for total lead in the laboratory, the sample would have to contain the same fractional soil percentages (gradation) as the raw soil shown above.

The mining-based solution when analyzing small arms range soils is to first determine the soil gradation and remove the particulate lead from each fraction using density separation techniques. Then, analyze each particulate-free soil fraction individually for total lead using USEPA methods. The residual total lead value for each fraction is then weight-averaged with the fractional percentage to derive the total residual lead value for the composite or "whole" soil.

Mining-Based Sample Collection

The number one challenge with regard to small arms firing ranges is an accurate and cost-effective assessment of total lead in soil. Large variation is prevalent at firing ranges because lead particulates are present in various size ranges and individual soil granules contain differing amounts of nonparticulate lead contamination.

The mineral processing industry has established guidelines for sample size to generate results that have a high confidence level and relative precision. Those guidelines are shown in Table 2. The table indicates that small arms range soil samples would need to be too large to analyze directly since soils can contain gravel particles 0.375 inch and larger in diameter, and bullets are in the range of 0.22 to 0.5 inches in diameter. Even if the soil was found to be uniform, more than 100 lbs. of sample are required.

Brice has developed field sample collection and reduction approaches that incorporate the required sample size to help control the adverse effects of sample heterogeneity. These approaches include:

- For impact berms at rifle and pistol ranges, use an excavator test trench in selected locales. A composite sample representing the vertical soil column and lead contamination can be collected from the walls and floor of the excavation. The vertical extent of lead contamination is typically driven by the visual presence of particulate lead. With this approach, the quantity of soil requiring treatment can be approximated.
- For trap/skeet ranges, typically only the top 6 inches to 1 foot of soil is contaminated. Excavating a series of small areas within the range can be performed with an excavator or shovel, based on the size of the area and the nature of the soil.
- Place the soil collected from each of the above approaches on a large tarp. The sample is then "rolled" and homogenized by lifting the corners of the tarp and mixing the soil. With two people, over 300 lbs of soil can be mixed using this approach. A 5-gallon subsample is then taken with a garden trowel from numerous random points.

The actual sampling steps employed are site-specific and a function of particulate lead distribution and soil gradation. A stratified sampling approach, done by dividing the area to be sampled into more homogeneous groupings, may be required to reduce variation in analytical results. A stratified sampling approach may be required for impact berms containing obvious bullet pockets with large depositions of lead, skeet ranges containing discrete areas of heavy lead shot accumulation, and firing ranges that utilized different soil types in the construction of the impact berm and range floor.

It is important when designing a sampling plan for a small arms firing range to recognize that

- uncertainty will never be reduced to zero, and
- the money spent collecting samples to reduce uncertainty should be balanced against the value of the reduced uncertainty.

Once a representative sample is collected, the next step is an accurate analysis of the sample for total lead.

Table 2. Required Sample Size as a Function of Sample Heterogeneity

	Sample Weight Needed for Various Ore Types		
Diameter of Largest Piece (in./mesh)	**Uniform Ore Sample Size (lbs.)**	**Medium Ore Sample Size (lbs.)**	**Heterogeneous Ore Sample Size (lbs.)**
0.5	250	556	3,200
0.375	141	313	1,800
0.312	98	217	1,250
0.25	63	139	800
0.1875/4	35	78	450
0.131/6	17.2	38.1	220
0.093/8	8.65	19.2	111
0.065/10	4.3	9.5	55
0.046/14	2.16	4.8	28
0.0328/20	1.075	2.37	13.76
0.0232/28	0.539	1.2	6.9
0.0164/35	0.269	0.59	3.44
0.0116/48	0.135	0.3	1.73
0.0082/65	0.067	0.15	0.86
0.0058/100	0.034	0.075	0.43
0.0041/150	0.017	0.038	0.215
0.0029/200	0.009	0.019	0.107

Source: Taggart, 1945

Both physical recovery techniques for particulate metal and USEPA methodology are required for an accurate assessment of lead contamination. Steps for performing this include

- a gradation determination,
- particulate metal recovery and a determination of total lead content (gravimetric analysis), and
- particulate-free fractional analysis for total lead using 8-g digested subsamples instead of 2-g digested subsamples.

The soil gradation is required because the fractional percentages will be utilized in the subsequent steps. Wet screening instead of dry screening should be utilized to ensure that each fraction is free of small soil granules, which may be more contaminated and, consequently, bias the analytical results.

Once the soil is wet-screened, each fraction should be density-treated to recover the particulate metal. The particulate metal recovered from each fraction should be dried, weighed, and the results recorded. Small arms firing range soils contain copper and zinc jackets, while the lead may contain hardening agents such as antimony. The recovered metal should be subjected to pyrometallurgical analysis to determine the percent lead as outlined below.

Mining-Based Sample Analysis

Contaminated soil samples from firing ranges are usually a heterogeneous mixture of matrix materials and contaminants. Individual granules of the soil samples can be significant relative to the size of a subsample taken for analysis, so the analytical results can vary considerably depending on the particular group of granules selected in the subsample. Variation caused by subsampling can be reduced by using a large subsample; but for heavy metals in particular, the digestion techniques for analysis of total metals usually call for a maximum subsample size of only 2 grams.

With no controls over the granules selected for digestion and ignoring the coarser soil fractions, analytical results for metals in soil can vary wildly. Brice has found that heavy metal contamination, for example, can vary by over two orders of magnitude between the finest soil fraction (minus 200-mesh) and medium sand (10- by 40-mesh) alone. Consequently, one sample that contains more minus 200 will generate a higher total metal result than a sample that contains more 10 x 40 soil and so forth. In summary, for an accurate determination of soil contamination, the sample analyzed has to contain the same fractional soil percentages (gradation) as the raw soil.

The situation regarding an accurate determination of soil contaminant levels is further compounded by the presence of particulate metal and organic matter. Clearly, particulate metal presents a significant source of variation when analytical subsamples are limited to several grams. Organic matter (leaves, sticks, grass, etc.) can also present a source of variation because it functions as a contaminant “sink” for organics and inorganics. Brice has found metal contamination in organic matter to be as high as three orders of magnitude above the contamination level of the soil at some sites, thus the impact of varying amounts of organic matter in the small subsample being analyzed can be significant.

The approach developed by Brice to accurately determine feed soil and post-treatment soil contaminant levels is as follows:

- Perform no composite soil analyses, but rather fractional analyses.
- Remove all particulate metal and organic matter from the specific fractions prior to any fractional analyses.
- Analyze the particulate- and organic-free soil fractions individually for listed contaminants.
- Increase the sample size to 8 grams for the conventional total metals acid digestion method.
- Weight-average the fractional soil analytical results with the percentage contribution of each fraction to derive the composite feed soil contaminant concentrations.
- Add the percentages of particulate metal from each fraction to derive the total percentage in the feed soil. Add the lead and copper determinations for the particulate metal to the feed soil concentrations.
- Add the percentages of organic matter from each fraction to derive the total percentage in the feed soil. Weight-average the contaminant contribution from the organic matter and add to the feed soil concentrations.
- Multiply the contaminant concentrations found in the water used for each sample with the volume of water used, and add to the feed soil concentrations.

By using larger subsample sizes and removing particulate metal and organic matter from the soil for separate analysis, soil contaminant concentrations will be more accurately derived. These sample preparation and analysis approaches will help control the adverse affects of sample heterogeneity and reduce the coefficient of variation in analysis results.

Gravimetric Analysis

The representative sampling and accurate analysis of soil containing particulate metal contamination is imperative to prevent erroneous results and bias. To avoid the “nugget effect” in feed soil analyses caused by particulate metals, the particulate metal will first be removed and accounted for in the soil fractions amenable to density treatment. The concentrations of lead, copper, zinc, and antimony in the recovered metal will then be determined by pyrometallurgical means. Note: Although zinc and antimony are not traditionally listed as metals of concern, the concentrations of these metals may affect recycling options and costs. Gravimetric results for lead and copper will then be added to the soil analytical results for those metals to yield more accurate feed soil concentrations.

Removing the particulate metal prior to analyzing the soil for metals reduces the coefficient of variation. In addition, the pyrometallurgical method overcomes three shortcomings of the conventional acidic extraction method used to prepare environmental samples for metals analysis:

- limited sample size,
- saturation of the extraction fluid, and
- inability to dissolve metal lumps.

The pyrometallurgical method involves taking a sample of the recovered particulate metal and blending it with sufficient carbon and borax to maintain a reducing environment and produce a stable slag that minimizes metal volatilization. The mix is then placed into a silicon carbide crucible and heated to 2,000 F until melting is complete.

Upon cooling, the slag is chipped away from each metal ingot and combined to form one slag sample. The ingot is sampled by drilling, followed by digestion and analyses of the drill cuttings. Both the ingot and slag are analyzed for lead, copper, antimony, and zinc, and the results from each product combined to generate the percentage of each element in the metal sample. The metal percentages are converted to mg/kg and added to the mg/kg nonparticulate metal results for the soil to derive total feed soil-metal concentrations.

The pyrometallurgical method is designed for analysis of metals in the percent range and is not subject to saturation effects that limit the maximum metal content that can be determined. Up to 4 lbs of sample can be smelted per crucible, thus sample heterogeneity and bias is substantially reduced when compared to the acidic digestion method for soils in which 0.5 to 2 grams of soil is typically used.

With this approach, the percentage of particulate metal in the soil can be determined, and the quantity of metal to be recovered can be estimated. The pyrometallurgical method reveals the quantity of lead, copper, zinc, and antimony in the recovered metal, enabling the recycling value, or recycling cost, to be determined.

Once the particulate metal is removed, each soil fraction (less than ¼ inch) should be digested in triplicate and analyzed for total lead. Oversize soil granules such as gravel and cobbles are generally too large to digest. Typically, when washed of fines, this rock contains no lead and subsequently does not require analysis.

Standard USEPA SW-846 Method 3051 is used for digestion of samples for total metals analysis. Increasing the sample size for digestion from 1 or 2 grams to 8 grams enhances the representativeness of samples from small arms firing ranges. The digestates can then be analyzed by flame AA or by ICP according to SW-846 Standard Method 6010.

The pyrometallurgical results will reveal the total lead content of the recovered particulate metal. The USEPA method results will reveal the total lead content of the particulate-free soil. The USEPA method results for each fraction should be weight-averaged with the percentage of each soil fraction to derive the nonparticulate total lead in the composite soil.

When the percent total metal from the soil is multiplied by the percent lead making up the particulate metal, the percent lead as particulate is determined. Adding the nonparticulate lead for the composite soil and the percent lead as particulate generates the accurate total lead in the soil.

APPENDIX C

Template: Scoping Document for Soil Washing Treatability Study and Engineering Report

Template: Scoping Document for Soil Washing Treatability Study
&
Engineering Report

XXXXXXXXXXX is currently performing remedial investigation activities at XXXXX.

Soils at the site contain particulate metal resulting from former firing range operations at the facility. The scope of this treatability study will involve bench-scale testing and analysis of soils from this site. Representative sample(s) will be analyzed to

- verify the effectiveness of mining-based soil washing/gravity separation techniques for the recovery of particulate metal and to
- determine what, if any, additional treatment is required to meet cleanup goals after soil washing.

Interested vendors must have the following qualifications and experience:

- treatability study and field experience employing density treatment soil-washing techniques on soils similar to those at this site,
- five successfully completed full-scale projects in which density treatment technology was part of the soil-washing treatment train,
- five years of soil-washing experience, and
- 15 treatability studies for which density treatment techniques were evaluated.

The study will include a step-wise evaluation of

- grain-size analysis/contaminant by fraction,
- contaminant removal by size segregation and gravimetric techniques,
- oversize-fragment removal by size segregation and screening, and
- post-treatment total and TCLP lead results for each individual size fraction.

The treatability study will focus first on material characterization of the sample, followed by optimizing treatment of specific fractions using physical treatment methods. Recoverable quantities of metals will be estimated in the treatability study in order to quantify the amount requiring recycling.

Treatment Processes

Soil-washing techniques evaluated during this treatability study should include the following:

- deagglomeration steps to separate sod/organic material from soil fractions,
- physical treatment employing wet screening for particulate partitioning, and
- density treatment to further separate geologic material from same-sized metal particulates.

Results of the treatability study will reveal the appropriate treatment approach for implementing the full-scale remediation. Treatment effectiveness will be presented in the treatability study report.

Analytical Methods

Treatability study analytical methods used must be based on their suitability to the soil matrix, level of soil contamination, analysis time, and reliability for treatment verification. The representative sampling and accurate analysis of soil containing particulate lead shot contamination is imperative to prevent erroneous results and bias. To avoid the "nugget effect" in feed soil analyses, initial lead concentrations will be determined gravimetrically. Once particulate lead has been removed and accounted for in the soil fraction amenable to density separation, AA analyses will be performed on the soil samples. Gravimetric results will then be added to the AA total lead results to yield more accurate feed soil concentrations.

Quality Control/Quality Assurance

Quality control (QC) objectives of the treatability study are to provide accurate, precise, and complete data sufficient to identify conditions under which lead is removed from contaminated soil. The primary comparison made during the bench study is between the contaminant level in the feed soil and the contaminant levels in treated soil following successive levels of treatment. This comparison will be made to determine the effectiveness of each step of the treatment process. Comparability will be assured by preparing and analyzing feed and treated soil under identical conditions.

Other QC checks to be employed during the treatability study include the use of check standards during AA analyses to ensure that the instrument is operating within acceptable limits of the calibration curve over a period to time. This will be performed during each analytical run. All in-house laboratory procedures and analytical results will be recorded in a bound laboratory notebook.

Soil Sampling

The treatability study will use one bulk 5-gallon composite soil sample from each area of concern collected from the site. Representatives of XXXXXXXX will perform soil sampling. The bucket of soil will be roll-mixed upon receipt at the treatability lab.

Gradation Analysis

Physical testing will begin with a visual inspection of the sample, followed by size gradation analysis to predict the physical behavior of the soil within process equipment and the usefulness of a soil classification step. Wet sieving will be used to separate the soil into its constituent particles of gravel, sand, and fines for an accurate determination of soil gradation. Individual soil fractions obtained form sieving will be oven dried and weighed to determine the distribution of particle sizes in the bulk soil. Sieve sizes used during the treatability study should simulate the generation of soil fractions appropriate to specific density-treatment processing equipment.

Contaminant Distribution and Feed Soil-Lead Concentration

During gradation analysis, particulate metal within each soil fraction will be retained with soil particles on the screens listed above. Particulate metal will then be separated from soil retained in each size fraction using density-based techniques. The mass of metal recovered from each soil fraction will be extrapolated into the entire soil volume.

Wet Screening

Wet screening will be evaluated for its ability to separate soils by size class.

Density Separation

Density-separation techniques will be evaluated for particulate metal removal. Different methods of density separation will likely be required for treating the different size classes of soil generated during screening. Water-pulse jigging and other density separation methods will be utilized to remove coarse and fine lead from the coarse and fine soil fractions, respectively. Observation of lead recovered and subsequent analysis of the treated soil will determine the efficiency of water-based density-separation techniques after dewatering and drying. At the conclusion of the physical treatment evaluation, the in-house total lead analytical results will be summarized.

Wash-Water Evaluation

The total lead concentration of the used wash water will be measured after the physical treatment evaluation is completed. If required, the wash water will be treated to reduce the solution lead concentration to meet the assumed discharge criterion of 5-mg/L lead. This concentration is typically the acceptance level for a publicly owned treatment works (POTW). Reagent consumption values will be generated to predict the chemical demand to treat wash water following a potential field-scale remediation project.

Soil Sample Disposal

After completion of the treatability study, soil samples will be returned to XXXXXXXXXXXXXX for replacement at the site.

Report

Following completion of the treatability study, a treatability study report will be prepared. The report will contain the following sections:

- Summary
- Methods
- Treatability Study Results
- Findings and Conclusions
- Recommendations

The Summary will present a brief statement of the findings of the treatability study. The Methods Section will review the methods used during the treatability study. The Treatability Study Results Section will contain tabulated analytical results. The Findings and Conclusions Section will highlight the significance of the findings of the treatability study results. The Recommendations Section will include recommended processes for the field-scale remediation, as well as a cost estimate for full-scale implementation.

Deliverables associated with this solicitation include

- treatability study proposal, including qualifications, technical approach, and pricing to complete the scope of work;
- past project experience in support of the qualifications listed above; and

- client references and phone numbers for completed projects listed.

APPENDIX D

Template: Scoping Document for Treatability Testing and Asphalt Emulsion Mix Design

Template: Scoping Document for Treatability Testing and Asphalt Emulsion Mix Design

INTRODUCTION

The scope of this treatability study is to do lab testing to develop an emulsion design for field implementation. The soil to be treated with ENCAPCO emulsions is contaminated with metals and organic contaminants and will subsequently be used as asphalt sub-base for paving projects. As such, the following parameters must be addressed:

- chemical fixation/treatment effectiveness and
- physical properties of treated soil.

Ultimately, the goal of the treatability study is to provide a mix design and procedures for field implementation that meet both the site reuse goals for treated soils as well as the physical characteristics to support the soil's intended end use.

Since the treated soil is to be used as a product, particulate metals must be removed prior to emulsion treatment. This particulate-removal step is critical as encapsulated heavy-metal particles could be re-exposed during placement or subsequent work on the treated sub-base material. Also, certain metals like copper are detrimental to the asphalt matrix and must be removed to ensure long-term structural integrity of the sub-base material.

To ensure effective particulate removal, all metal-leachability testing will be done after the emulsion mix has cured, been strength tested, and the cured sample subsequently pulverized. The aliquot selected for leachability testing will be taken from the pulverized sample.

The initial step of the treatability study will include a step-wise evaluation of density separation for particulate metals consisting of

- grain-size analysis/containment by fraction,
- contaminant removal by size segregation and gravimetric techniques,
- oversize-fragment removal by size segregation and screening, and
- post-treatment and TCLP metal results for each individual size fraction.

The treatability study will focus first on material characterization of the sample, followed by optimizing treatment of specific fractions using physical treatment methods. Recoverable quantities of metals will be estimated in the treatability study to quantify the amount requiring recycling. Once completed, residual soils free of particulate metals will undergo subsequent emulsion treatability studies.

DENSITY SEPARATION TREATMENT PROCESS

Density separation/soil-washing techniques evaluated during this treatability study should include the following:

- deagglomeration steps to separate sod/vegetative material from soil fractions,
- physical treatment employing wet screening for particulate partitioning, and
- density treatment to further separate geologic material from same-sized metal particulates.

Results of the treatability study will reveal the appropriate treatment approach for implementing the full-scale remediation. Treatment effectiveness will be presented in the treatability study report.

Analytical Methods

Treatability study analytical methods used must be based on their suitability to the soil matrix, level of soil contamination, analysis time, and reliability for treatment verification. The representative sampling and accurate analysis of soil containing particulate lead shot contamination is imperative to prevent erroneous results and bias. To avoid the "nugget effect" in feed soil analyses, initial metal concentrations will be determined gravimetrically. Once particulate metal has been removed and accounted for in the soil fraction amenable to density separation, AA analyses will be performed on the soil samples. Gravimetric results will then be added to the AA total lead results to yield more accurate feed soil concentrations. Recovered metal concentrates will undergo a metallurgical assay to aid in developing potential recycling scenarios.

Quality Control/Quality Assurance

Quality Control (QC) objectives of the treatability study are to provide accurate, precise, and complete data sufficient to identify conditions under which lead is removed from contaminated soil. The primary comparison made during the bench study is between the contaminant level in the feed soil and the contaminant levels in treated soil following successive levels of treatment. This comparison will be made to determine the effectiveness of each step of the treatment process. Comparability will be assured by preparing and analyzing feed and treated soil under identical conditions.

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Gradation Analysis

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Contaminant Distribution and Feed Soil-Metal Concentration

During gradation analysis, particulate metal within each soil fraction will be retained with soil particles on the screens listed above. Particulate metal will then be separated from soil retained in each size fraction using density-based techniques. The mass of metal recovered from each soil fraction will be extrapolated into the entire soil volume.

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Wet screening will be evaluated for its ability to separate soils by size class.

Density Separation

Density separation techniques will be evaluated for particulate metal removal. Different methods of density separation will likely be required for treating different size classes of soil generated during screening. Water-pulse jigging and other density separation methods will be utilized to remove coarse and fine lead from the coarse and fine soil fractions, respectively. Observation of lead recovered and subsequent analysis of the treated soil will determine the efficiency of water-based density separation techniques after dewatering and drying. At the conclusion of the physical treatment evaluation, the in-house total lead analytical results will be summarized.

Wash-Water Evaluation

The total lead concentration of the used wash water will be measured after the physical treatment evaluation is completed. If required, the wash water will be treated to reduce the solution metal concentration to meet the required discharge criterion. Reagent consumption values will be generated to predict the chemical demand to treat wash water following a potential field-scale remediation project.

ENCAPCO EMULSION DESIGN PROCESS

Organic-based emulsions are effective in stabilizing and immobilizing some heavy metal–contaminated soils as determined by the TCLP method. Additionally, the soil/emulsion system can be engineered through conventional methodology to produce a product suitable for road construction or various engineered fill purposes. The process can be used for on-site treatment by excavation, mixing, and compaction, or by excavation, mixing, and transport to a remote site for later use. The process is designed to comply with USEPA 40 CFR 266.206 (b) (i.e., use constituting disposal or recycling) and has the following attributes:

- Stabilization of heavy-metal species in the emulsion/soil matrix, rendering contaminants inaccessible for dissolution into water bodies.
- Creation from hazardous waste of a product suitable for use in the construction industry.
- Capability through accepted chemical and civil engineering practice to design reliable systems resulting in the above bulleted uses.

Following is a description of the engineering process.

Emulsion Treatment Approach

When recycling metals-contaminated soil for use as a structural material, the structural capabilities of the soils must be evaluated while at the same time treating the metals contamination. The soil is stabilized with an emulsion to improve strength and durability. The same emulsion contains an additive to bind the metal to the soil and prevent it from leaching out.

To recycle the contaminated soil in this manner, the final soil mix design must be a balance of the correct amount of mix water, emulsion, and emulsion additive. Lime or cement is also added to improve the cure time of the emulsion-stabilized soil to facilitate construction schedules.

In any application of this technology, a site-specific engineering evaluation must be undertaken. The following steps outline our general engineering approach when the recycled product is to be used as a road base:

Step 1. AASHTO Soil Classification

During this step, the gradation, liquid limit, plasticity index, and moisture density curve are determined. The soil can then be classified according to ASSHTO and some feeling for the soil as a structural material obtained.

The optimum moister is needed to determine the amount of mix water to be added along with the emulsion so that maximum density can be achieved.

Step 2. Metals Analysis

The contaminated soil is tested to determine the level of metal in the soil. USEPA Test Method 3050A and 7420A are used to determine the total content (TTLC), and USEPA Test Method 3010A and 7420 are used to determine the leachable concentration as optimized in Step 5.

Step 3. Determine Starting Soil Mix Design

Using the data from Steps 1 and 2 and a knowledge of the end product desired, the additive level and base stock (i.e., asphalt or tall oil pitch) is selected for the emulsion. Three emulsion levels and three lime levels are selected for a total of nine (9) samples to be tested in Step 4. The lime is necessary to optimize curing, mixing, and strength characteristics of the product.

Step 4. Strength Testing, ASTM 1559

During this step, Marshall specimens are fabricated for each of the samples referenced in Step 3 at about optimum water content. The specimens are allowed to cure under conditions anticipated at the site. Marshall stability and flow tests are run on the samples. From the data generated, optimum emulsion and lime content can be determined.

Step 5. Treatability Analysis (Evaluate Leachability of Metal)

A soil sample is prepared at the optimum soil design and tested for TTLC and TCLP (see test methods listed in Step 2). A sample that was tested in Step 4 that is at a near-optimum design may be used in this step. If the TCLP results satisfy the USEPA specification and the sample from Step 4 was tested, Step 6 may be skipped. If the USEPA specification is not satisfied and the additive needs to be adjusted, then a recheck of the strength is needed and Step 6 is required.

Step 6. Final Mix Design Verification

If the additive level is changed from the level in the emulsion in Step 4, a recheck is required. This involves preparing a single set of samples at optimum lime, emulsion, additive, and water and performing a Marshall stability test.

Step 7. Material Design

Using the Marshall stability obtained in Step 4, a structural coefficient for the recycled material can be determined. The Marshall stability relationship for bituminous-treated base is contained in the AASHTO guide for design of pavement structures. This structural coefficient can then be used in the design of the road section to be constructed.

Depending on the end use of the recycled material, other design procedures may be appropriate. For instance, if the end use of the treated soils is for a granular base or sub-base, the compressive strength characteristics of the soils should be investigated using Resistance R-Value, CBR, or unconfined compressive strength.

Prior to initiating the emulsion design work, an initial soil-washing treatability study will be conducted. This study will evaluate the grain-size distribution of the impacted soil and the optimum screening “cut-points” for wet screening the soil into fractions suitable for gravity separation of gross metal particulate, as described in previous sections.

This study should document the volumes of material generated at each cut, together with the costs associated with the screening steps. From this information, a stabilization/reuse treatability study can be conducted in accordance with the steps detailed above. The only modification to our customary approach would be evaluating what, if any, reaggregation is needed to meet the recycled material end use structural requirements. It might also allow the emulsion content or chemical makeup to be adjusted in a manner proving to be more cost-effective.

Soil Sample Disposal

After completion of the treatability study, soil samples will be returned to the site for replacement at the site.

Report

Following the completion of the treatability study, a treatability study report will be prepared. The report will contain the following sections:

- Summary
- Methods
- Treatability Study Results
- Findings and Conclusions
- Emulsion Mix Design
- Recommendations

The Summary will present a brief statement of the findings of the treatability study. The Methods Section will review the methods used during the treatability study. The Treatability Study Results Section will contain tabulated analytical results. The Findings and Conclusion

Section will highlight the significance of the findings of the treatability study results. The Emulsion Mix Design will provide a summary of the optimized mix design/performance. The Recommendations Section will include recommended processes for the field-scale remediation, as well as a cost for full-scale implementation.

Deliverables associated with this solicitation include

- treatability study proposal, including qualifications, technical approach, and pricing to complete the scope of work;
- past project experience in support of the qualifications listed above; and
- client references and phone numbers for completed projects listed.

APPENDIX E

White Paper on Created Wetlands for Range Runoff Control

Charles Harman
AMEC Earth and Environmental
285 Davidson Avenue, Suite 100
Somerset, New Jersey
Charles.harman@amec.com

EFFICACY OF USING PASSIVE CONSTRUCTED WETLAND SYSTEMS TO PREVENT MIGRATION AND EROSION OF LEAD FROM SMALL ARMS RANGES

White Paper on Created Wetlands for Range Runoff Control

Charles Harman AMEC

EFFICACY OF USING PASSIVE CONSTRUCTED WETLAND SYSTEMS TO PREVENT MIGRATION AND EROSION OF LEAD FROM SMALL ARMS RANGES

The use of lead-containing ammunition at small arms firing ranges results in a continual contribution of lead into the environment. Lead accumulates in berms and other structures used to backstop targets on ranges. Bullets will lodge into the berm either whole or in fragments. Once there, the erosional processes of storm water can result in the movement of these fragments off the berm and into the environment. In cases where the storm water and/or soils in and around the berm are acidic, lead may leach from the bullets or fragments, further dispersing into the environment. As noted in USAEC (1998), the dispersal of lead through these mechanisms results in a potential ecological risk and may be in violation of the Clean Water Act, the Safe Drinking Water Act, and Section 7003 of the Resource Conservation and Recovery Act (RCRA).

As various methods of active and passive controls are being investigated to halt the migration of lead from firing ranges and limit both the liability and risk associated with this metal, it is my contention that the use of constructed wetlands should be considered as one of the tools in this process. The rationale is that as distinct ecological units, wetlands perform certain functions in their positions on the landscape (Mitsch and Gosselink, 1993). Functionally, wetlands play a role in flood conveyance, flood storage, sediment control, and as habitat for various biota. However, the critical function from a range standpoint is the improvement of water quality through either filtration or biochemical processes (NWPF, 1988).

This white paper discusses the efficacy of using constructed wetlands to prevent the migration of lead from small arms firing ranges and into the environment.

Wetlands Overview

Wetlands are unique and sensitive ecological units and provide valuable functions in the natural environment. These functions include providing necessary breeding habitat for a variety of organisms such as waterfowl, fish, and shellfish; erosion and storm water flood control; groundwater recharge; and nutrient transport. Wetlands can be found in freshwater, brackish, and saline conditions and can be found along coasts, in forests, and along rivers or creeks. They can be found anywhere that the saturated soil conditions necessary for wetland development exist.

Hydrology is probably the single most important determinant for the establishment and maintenance of specific types of wetlands and wetland processes. It is the permanent or periodic saturation of a wetland area that results in the anaerobic conditions in the soil under which typical wetland biogeochemical processes occur. The result of these processes is the development of characteristic wetlands soils, which will support a dominant plant community adapted to living in saturated soils. The hydrologic state of a wetlands can be represented by a hydrologic budget, which is essentially the difference in the amount of water moving into the wetlands and the amount of water moving out. Factors that influence wetlands water budgets include: 1) the balance between inflows and outflows of water; 2) surface contours of the landscape; and 3) subsurface soil, geology, and groundwater conditions.

Overview of Constructed Wetlands

Constructed wetlands are engineered structures that bring together wetlands components (plants, soils, and hydrology) into positions on a landscape that is not presently occupied by a wetlands (or a fully functioning wetlands). The term “constructed wetlands” refers to wetlands that have been designed for water quality treatment purposes (Hammer, 1992). The benefits provided by constructed wetlands include the natural filtering of sediments and other constituents of concern from water flowing through them. The aim is to construct wetlands that mimic the actions of a natural system and, therefore, can be utilized to improve water quality or manage storm water.

In general, there are two types of wetlands constructed for water treatment purposes: surface flow (SF) and subsurface flow (SSF) wetlands (Kadlec and Knight, 1996). SF wetlands (sometimes called free water surface wetlands (FW) (Reed and Brown, 1992) are densely vegetated by a variety of wetlands plant species and have depths less than 1.5 feet (though several authors note deeper uniform depths). Open water areas may be incorporated into the design. Capital expenditures for the construction of SF wetlands typically range from \$10,000 to \$100,000/ha, primarily as a result of earthwork (Knight, et al., 1993). Based on a review of 19 FW wetlands constructed in the southeastern United States, Reed and Brown (1992) found an average construction cost of \$55,000/ha (\$22,000/acre) from project inception.

SSF wetlands utilize a bed of soil or gravel as a substrate for the growth of rooted vegetation and rely on gravity to move water through the system. Bed depth of a SSF wetland is usually less than 2 feet (Kadlec and Knight, 1996). Capital expenditures for the construction of an SSF wetlands typically ranges from \$100,000 to \$200,000 (Knight, et al., 1993). Based on a review of 18 SSF wetlands constructed in the southeastern United States, Reed and Brown (1992) found an average construction cost of \$215,000/ha (\$87,000/acre) from project inception. WPCF (1990) reported an average operation and maintenance cost for both SF and SSF wetlands ranging from \$0.03 to $\$0.09/m^3$.

The actual form that a constructed wetlands may take is a function of numerous issues, including space, cost, constituents to be addressed, aesthetic needs, and pollutant loads. Constructed wetlands are often built as a series of cells, which allow for an increase in efficiency and ease of maintenance. Wetlands can be ponds, marshes, simple detention basins, or combinations thereof. Depending on the permeability of the soil, constructed wetlands can be either lined or unlined.

Lead in the Environment

Lead occurs in the environment (particularly in surface waters) most often in the divalent form (Pb (II)). This form tends to form salts with sulfides, carbonates, sulfates, and chlorophosphates. Lead combines with organic ligands to form soluble complexes and is likely to be insoluble above a pH of 8.5, with increasing solubility at lower pH values (Kadlec and Knight, 1996). Lead is most soluble and bioavailable under conditions of low pH; low organic content; low concentrations of suspended sediments; and low concentrations of calcium, iron, manganese, zinc, and cadmium salts (Eisler, 2000). Vymazal (1995) notes that sorption to sediments plays a very important role in the fate of lead complexes in the environment. May and McKinney (1981) note that most lead entering natural waters is precipitated to the sediment bed as carbonates or hydroxides. At low stream flows, lead is rapidly removed from the water column by sedimentation (Benes, et al., 1985).

Lead is toxic to most ecological receptors. Excessive amounts of lead result in growth inhibition and impairment of biochemical processes in plants. Ingestion of lead shot has resulted in direct mortality in a wide variety of waterfowl species, as well as over 30 other avian species. Lead is toxic to all manner of aquatic biota, though the effects can be significantly modified by various biological and abiotic variables (Wong, et al., 1978). In mammals, lead modifies the function and structure of the kidney, bone, the central nervous system, and the hematopoietic system (Eisler, 2000).

Efficacy of Lead Removal

Wetlands remove metals such as lead, copper, chromium, and arsenic from water through a variety of biogeochemical processes. Wetlands remove metals through filtration of suspended particles out of the water column, uptake and absorption of metals by plants within the wetlands, and precipitation of the metals as a result of adjustments in pH. The ability of wetlands to remove metals is generally a function of the high proportion of humic material and other organic substances found within the wetlands substrate (Wildeman, et al., 1991). The processes of note include adsorption onto plants or soil particles, ion exchange, bioaccumulation, bacterial and abiotic oxidation, sedimentation, neutralization, reduction, and dissolution of carbonate materials (Perry and Kleinman, 1991). Sobolewski (1997) notes that plant roots will retain arsenic, lead, and other metals. Schooner (1997) notes that emergent and submergent aquatic plants within created wetlands will remove lead, copper, nickel, cadmium, and zinc through rhizofiltration processes.

Fennessy and Mitsch (1989) note that soluble metals are converted to insoluble forms as a result of the anoxic conditions found within wetlands sediments. One of the control factors in this function is the pH of the supporting waters. In acidic waters, metals are soluble and tend to remain mobilized. In waters with higher pH, the metals are insoluble and are acted upon by adsorption and precipitation mechanisms. Therefore, one of the features of a constructed wetlands is a mechanism such as a limestone barrier to raise the pH and precipitate out the metals.

The removal efficiency of lead increases with the concentration of the inflow supporting water source. Kadlec and Knight (1996) note that lead removal in wetlands is primarily accomplished through formation of insoluble compounds in the water column, followed by subsequent sedimentation. Schiffer (1989) reported removal efficiencies of 83.3% for a marsh wetlands in Florida receiving urban runoff, while USEPA (1993) reported removal efficiencies of 45% for vegetative filter strips and 65% in constructed storm water wetlands. In evaluating the available literature, Kadlec and Knight (1996) concluded that SF marshes and SSF wetlands are effective at removing lead from storm water.

Mæhlum (1999) cites a large number of studies in cold weather (mean temperatures below 26.6° F in winter and above 50° F in the summer) regions of the world (Canada, northern United States, Scandinavia, and eastern Europe) documenting the success of constructed wetlands in treating wastewaters. He reports that the processes that primarily affect metals in wetlands (sorption and precipitation) are unaffected by temperature. Kadlec and Knight (1996) support this premise.

Conceptual Design

The primary mechanism to remove lead in a constructed wetlands is precipitation of lead hydroxides, due to oxidation within aerobic sediment zones and sulfate reduction to insoluble metal sulfides in anaerobic sediment zones. Both the dissolved and precipitated lead will contact adsorptive surfaces and ion-exchange sites provided by both plant and sediment surfaces, allowing the lead to be fixed into the organic base of the developing constructed wetlands. The full efficiency of such a system is not expected to occur until after two or three growing seasons have allowed the full establishment of the plant material within the constructed wetlands (Loer, et al., 1999).

Designing a constructed wetlands to address lead migration is a function of several considerations, including loading rate, retention time, slope, substrate, vegetation, season, and sediment control. The most critical element in designing the wetlands is in calculating the hydrologic characteristics of the system. That means the wetlands under design must be constructed deep enough to contact groundwater on a periodic basis; or if groundwater is deep, then the substrate of the wetlands must be impervious enough to retain water. This will allow for the creation of anaerobic conditions in the sediment zone, which would lead to the development of a strong organic or humic layer for binding lead moving through the system.

A passive wetlands system could be designed to receive storm water runoff from small arms firing ranges. The constructed wetlands could be placed at either the toe of the berm slope so as to receive sheet flow runoff from the berms, or designed to receive storm water through channels that contain and direct storm water runoff. The wetlands could be designed in combination with biofilters (using the storm water channel as prefilters to remove large particles prior to polishing in the wetlands) and/or detention basins to allow the settling of large-particle sediments prior to discharge of the storm water into the constructed wetlands. The designed slope for such systems should be between 1% and 5% (USEPA, 2000). In circumstances where the supporting water is acidic, anoxic limestone drains or other mechanisms can be introduced to raise the pH and allow for lead precipitation.

As part of a conceptual constructed wetlands to address arsenic, chromium, and copper dissolved in storm water at a site in Florida, modifications to storm water channels and retention basins were proposed. The anticipated effect was to reduce storm water infiltration and increase storm water residence time through the installation of a low-permeability liner to the channel and/or the basin, followed by the planting of wetlands vegetation to develop the organic base for retention of the metals. Initially, excavation and grading of the existing channel and basin would be performed to contour the subgrade. The channel and basin would be lined with a low-permeability liner consisting of a geosynthetic clay liner (GCL) or compacted low permeability soil (e.g., clay). Vegetative soil material (e.g., topsoil) would be placed above the liner and further covered with a layer of humic material (*Sphagnum* or peat moss) to facilitate organic binding of metals. Soils would be a sandy loam and contain approximately 8% to 10% organic matter. The channel basin would be planted with a combination of native emergent wetlands species that are known to remove metals from surface water. All plants would be planted on one-foot centers, with the planted stock being 2-inch plugs.

Loer, et al. (1999) presents a study of a diverse, integrated treatment system, which included sedimentation basins and constructed wetlands, to address metals in landfill leachate. When in operation, their system, constructed in Minnesota, had a lead-removal efficiency of 80%.

Conclusions

A review of the literature and experience with constructed wetlands suggest that the use of these passive wetlands systems would be an optimal approach to cost effectively control lead migration from small arms firing ranges. Lead is a metal easily managed by the biogeochemical processes present in functional wetlands, and the filtration of this material is within the expected functional performance of wetlands. It is recommended that continued studies, including field pilot studies, be conducted to evaluate the efficacy of these systems.

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APPENDIX F

Baseline Risk Assessment

BASELINE RISK ASSESSMENT

1. General Information

Baseline risk assessment (BRA) provides an evaluation of the potential threat to human health and the environment in the absence of any remedial action. It provides the basis for determining whether or not remedial action is necessary. Detailed guidance on evaluating potential human health impacts are provided in *Risk Assessment Guidance for Superfund* (RAGS), EPA/540/1-89/002, December 1989. Detailed guidance on evaluating potential ecological impacts is provided in *Ecological Risk Assessment Guidance for Superfund* (ERAGS), EPA/540-R-97-006, August 1997.

In general, the objectives of a BRA may be attained by identifying and characterizing the following:

- Toxicity and levels of hazardous substances present in relevant media (e.g., soil, groundwater, etc.)
- Environmental fate and transport mechanisms within specific environmental media such as physical, chemical, and biological degradation processes and hydrogeological conditions
- Potential human and ecological receptors
- Potential exposure routes and extent of actual or expected exposures
- Extent of expected impact or threat, and the likelihood of such impact or threat occurring
- Level(s) of uncertainty associated with the factors used to derive the risk estimate

The goal of the BRA is to gather sufficient information to adequately and accurately characterize the potential risk from a site.

2. Components of a BRA

The risk assessment process can be divided into four components:

- Contaminant identification
- Exposure assessment
- Toxicity assessment
- Risk characterization

a. Contaminant Identification

The objective of this component is to screen information that is available on substances that may have been released on the site in order to identify chemicals to focus subsequent efforts in the risk assessment process. Chemicals of potential concern (CoPCs) are selected because of their intrinsic toxicological properties, because they are present in large quantities, or because they are present in, or may migrate into, critical exposure pathways.

b. Exposure Assessment

The objectives of this component are to identify actual or potential exposure pathways, to characterize the potentially exposed populations, and to determine the extent of the exposure. Identifying potential exposure pathways helps to conceptualize how chemicals may migrate from a source to an existing or potential point of contact. An exposure pathway may be viewed as consisting of four elements: (1) a source and mechanism of chemical release to the environment; (2) an environmental transport medium; (3) a point of potential contact between a receptor and an environmental media; and (4) an exposure route to the receptor at the point of contact (e.g., ingestion, dermal). Once the source(s) and release mechanisms have been identified, an analysis of the environmental fate and transport of the chemicals can be conducted. This analysis considers the potential migration, transformation, and transfer mechanisms to provide information on the potential magnitude and extent of the contamination. This is a vital part of developing your conceptual site model. From this information, the actual or potential exposure points for receptors can be identified. The focus of this effort should be on those locations where actual contact with the CoPC will occur or is likely to occur. Last, potential exposure routes that describe the potential for the CoPC to enter the receptor's body is identified and described.

After the exposure pathway analysis is completed, the potential for exposure needs to be assessed. Information on the frequency, mode, and magnitude of exposure(s) has to be gathered. These data are then combined to yield a value that represents the amount of affected media contacted per day. This analysis needs to be done for both the current situation and the exposures that are expected to occur in the future if no action is taken at the site. Therefore, as part of this evaluation, a reasonable maximum exposure scenario needs to be developed, which reflects the type(s) and extent of exposures that could occur based on the likely and expected use of the site.

c. Toxicity Assessment

This assessment considers (1) the types of adverse health or ecological effects associated with individual and multiple chemical exposures, (2) the relationship between magnitude of exposures and adverse effects, and (3) related uncertainties such as the weight of evidence for a chemical's potential carcinogenicity in humans. Typically, the BRA process relies heavily on existing toxicity information and does not involve the development of new data.

d. Risk Characterization

In this final component, the chemical concentrations, exposures, and toxicities are combined to develop an estimate of risks of adverse effects. This final analysis includes a summary of the risks associated with a site. It consists of risks associated with each exposure route, media, and CoPC, as well as a total risk for each exposure scenario for both carcinogenic and noncarcinogenic effects.

e. Lead

The methodology used for assessing risk from lead differs from that used for other chemicals. It relates soil and airborne lead concentrations to blood-lead concentrations in the exposed population according to the equations described below. The most sensitive receptor for these equations is the fetus of a pregnant female worker/resident; however, it also calculates the blood level of the adult. This receptor was chosen since the fetus of a pregnant worker is more sensitive to chemical exposure than a regular adult or child receptor.

The effects of lead are the same regardless of the route it enters the body. The major health threat from lead arises from the effects on the nervous system, especially in fetuses, infants, and young children. Fetal exposure may result in preterm birth, reduced birth weight, and decreased IQ.

Lead exposures may increase blood pressure in middle-aged men. High-level exposure can affect the brain and kidneys in adults or children. In addition, high doses of lead may lead to abortion and damage to the male reproductive system.

a. The basis for the calculation of the blood-lead concentration in adults and women of child-bearing age is the algorithm given by Equation 1:

$$PbB_{adult,central} = PbB_{adult,0} + \frac{PbS \bullet BKSFs \bullet IR_S \bullet AF_S \bullet EF_S}{AT} + \frac{Pba \bullet BKSFa \bullet AFa \bullet EFa}{AT}$$

where:

$PbB_{adult,\ central}$ = Central estimate of blood-lead concentrations (ug/dL) in adults (i.e., women of child-bearing age) that have site exposures to soil and airborne lead at concentration, PbS/Pba.

$PbB_{adult,\ 0}$ = Typical blood-lead concentration (ug/dL) in adults (i.e., women of child-bearing age) in the absence of exposures to the site that is being assessed.

PbS/Pba = Soil/air lead concentration (ug/g)/(ug/m3) (appropriate average concentration for individual).

BKSFs/a = Biokinetic slope factor relating (quasi-steady state) increase in typical adult blood-lead concentration to average daily lead uptake (ug/dL blood-lead increase per ug/day lead uptake).

IR_S = Intake rate of soil, including both outdoor soil and soil-derived dust (g/day).

AF_S = Absolute gastrointestinal absorption fraction for ingested lead in soil and lead in dust derived from soil (dimensionless).

AFa = Respiratory absorption fraction for inhaled lead in air (dimensionless).

$EF_{S/a}$ = Exposure frequency for contact with assessed soils/air (days of exposure during the averaging period).

AT = Averaging time; the total period during which soil contact may occur.

b. The root of equation 2 is the relationship between the soil and airborne lead concentration, and the blood-lead concentration in the developing fetuses of adult women that have site exposures. As a health-based goal, USEPA has sought to limit the risk to young children of having elevated blood-lead concentrations. USEPA, following the suggestions of the Centers for Disease Control, has defined an elevated blood-lead concentration as exceeding 10 ug/dL to 5% of the exposed target population. Equation 2 describes the estimated relationship between the blood-lead concentration in adult women and the corresponding 95th percentile fetal blood-lead concentration ($PbB_{fetal,\ 0.95}$).

$$PbB_{fetal,0.95} = PbB_{adult,central} \bullet GSD_{i,adult}^{1.645} \bullet R_{fetal/maternal}$$

where:

$PbB_{adult,central,goal}$ = Goal for blood-lead concentration (ug/dL) in adults (i.e., women of child-bearing age) that have site exposures. The goal is intended to ensure that $PbB_{fetal,\ 0.95,\ goal}$ does not exceed 10 ug/dL.

$PbB_{fetal,\ 0.95,\ goal}$= Goal for the 95th percentile blood-lead concentration (ug/dL) among fetuses born to women having exposures to the specified site soil and air. This is interpreted to mean that there is a 95% likelihood that a fetus, in a woman who experiences such exposures, would have a blood-lead concentration no greater than $PbB_{fetal,\ 0.95,\ goal}$.

$GSD_{i,\ adult}$ = Estimated value of the individual geometric standard deviation (dimensionless); the GSD among adults (i.e., women of child-bearing age) that have exposures to similar on-site lead concentrations but that have nonuniform response (intake, biokinetics) to site lead and nonuniform off-site lead exposures.

$R_{fetal/maternal}$ = Constant of proportionality between fetal blood-lead concentration at birth and maternal blood-lead concentration (dimensionless).

Equations 1 and 2 are based on the following assumptions:

- Blood-lead concentrations for exposed adults can be estimated as the sum of an expected starting blood-lead concentration in the absence of site exposure ($PbB_{adult,\ 0}$) and an expected site-related increase.

- The site-related increase in blood-lead concentrations can be estimated using a linear biokinetic slope factor (BKSF), which is multiplied by the estimated lead uptake.

- Lead uptake can be related to soil and airborne lead levels using the estimated soil and airborne lead concentration (PbS/PbA), the overall rate of daily soil ingestion (IR_S), and the estimated fractional absorption of ingested lead/respired lead ($AF_{S/a}$). Soil exposure is assumed to be limited predominantly to top layers of the soil, which gives rise to human contact.

- The default value recommended by USEPA for IR_S (0.05 g/day) is intended for occupational exposures that occur predominantly indoors. More intensive soil contact would be expected for predominantly outdoor activities such as would occur at a firing range. For this reason, we are using a value derived by USEPA for outdoor activity (0.48 g/day).

- A lognormal model can be used to estimate the variability in blood-lead concentrations between individuals.

- Expected fetal blood-lead concentrations are proportional to maternal blood-lead concentrations.

3. Application of the BRA Process to Small Arms Ranges

While most of the general BRA process applies directly to a small arms range, a few of the steps can be modified to address the special circumstances of these ranges.

a. Contaminant Identification

While the evaluation of a generalized hazardous waste investigation site involves the consideration of a full target analyte list of chemical parameters, the focused nature of a small arms range provides some opportunity to similarly focus the analytical suite. Unless otherwise indicated in the site history, the use of small arms ranges is limited to projectiles of small caliber (less than 0.50 caliber). These projectiles are overwhelmingly lead or copper-jacketed lead with a few being some other metal, usually steel or a polymer. The remainder of the ammunition is composed of a casing (usually brass, steel, or tin); a primer composed of a metallic fulminate, styphnate, or azide compound (usually lead); and a propellant (granular, smokeless powder, or black powder). Modern propellants are composed of nitrocellulose or of nitrocellulose and nitroglycerine mixtures. Both the propellants and the primer are rapidly burning materials that leave little residue as either decomposition products or uncombusted compounds. Additionally, both the original compounds and the decomposition products are mostly analyzed as common soil compounds, which are difficult to evaluate (Organic carbon, CO2, nitrates, etc,). As such, the analytical suite can be focused on metals, mostly lead and copper.

[**CALIBER:** The nominal diameter of a projectile of a rifled firearm, usually expressed in hundreds of an inch. Abbreviated Cal. As a loose rule, the larger the decimal fraction, the "higher" the caliber and the more powerful the ammunition (e.g., a .22 caliber is smaller and weaker than a .45 caliber). To put "caliber" in a general context, a .22 is the smallest common caliber. Calibers ranging from .22 to .32 are considered "light" and are best suited for target shooting. Calibers from .38 to .45 (which includes the common 9 mm and .357 magnum) are commonly selected by law enforcement agencies as "defensive calibers." "Heavy" calibers such as .44 magnum, .454 Casuals, and .50 cal produce incredible amounts of energy and may require special care with respect to a safe shooting area.]

b. Exposure Assessment

The exposure assessment is highly dependent on the current and future land use expected for the site. While the general method handles most uses adequately, one existing and future use is not adequately addressed without modification. When a small arms range is to continue its operation, the risk assessment should be based on the range's impact on groundwater with no quantitative ecological risk assessment, unless a migratory pathway away from the range can be established.
The reasons for this type of assessment are not obvious. If the range is to continue to be used, metallic deposition in the backstop/berm area will continue. The only human receptors will be

site workers, who are covered by the exposure standards of the Occupational Safety and Health Administration (OSHA). For safety, site visitors are not allowed near the backstop/berm area, thus eliminating their exposure. Ecological concerns are addressed by the nature of the range operation.

APPENDIX G

Acronyms

Acronyms

APC	Air Pollution Control
ARAR	Applicable or Relevant and Appropriate Requirement
ASTM	American Society of Testing and Materials
BNA	Base/Neutral/Acid
BRA	Baseline Risk Assessment
BRAC	Base Realignment and Closure
CAMU	Corrective Action Management Unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CEM	Continuous Emissions Monitor
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
CO	Carbon Monoxide
CoPC	Contaminant of Potential Concern
DCA	Dichloroethane
DCE	Dichloroethene
ERA	Ecological Risk Assessment
EPA	Environmental Protection Agency
GC/ECD	Gas Chromatograph/Electron Capture Detector
GC/MS	Gas Chromatograph/Mass Spectrometer
ITRC	Interstate Technology and Regulatory Council
NPL	National Priority List
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PIC	Products of Incomplete Combustion
POC	Point of Contact
POP	Proof of Process
POTW	Publicly Owned Treatment Works
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
SAFR	Small Arms Firing Range
SMART	Small Arms Range Team
SMPD	Scientific Management Decision Point
SPOP	Sustainable Practices and Opportunities Plan
SPLC	Synthetic Precipitation Leaching Procedure
TCLP	Toxicity Characteristic Leaching Procedure
TDU	Thermal Desorption Unit
TSD	Treatment, Storage, and Disposal
TSCA	Toxic Substances Control Act
USEPA	U.S. Environmental Protection Agency

APPENDIX H

ITRC Small Arms Firing Range Team Response to Comments from the POC Preconcurrence Review and the U.S. Army Environmental Center

Illinois

1. Comment

A number of the regulatory interpretations included in the ITRC document are essentially policy decisions that are better left up to the individual states to decide. We have found that the regulations related to lead shot and contaminated soils at shooting ranges are being interpreted differently across the USEPA regions and by various states. These policies have been shaped by the following court cases:

Review of *Connecticut Coastal Fisherman's Assoc. v. Remington Arms Co.*, 989 F.2d 1305 (2d Cir.1993) and review of previous Illinois EPA documents and correspondence is that this determination of the material meeting the definition of a solid waste is applicable **only** (emphasis added) if the lead, where it has been applied to the land, poses an imminent hazard as defined by RCRA.

The U.S. Court of Appeals, Second Circuit, evaluated the lead shot issue in *Connecticut Coastal Fishermen's Assoc. v. Remington Arms Co.*, 989 F.2d 1305 (2d Cir.1993) (the stated basis for the determination that the lead shot meets the regulatory definition of a solid waste) and modified the USEPA position somewhat. In addition to decisions based on procedural issues involving citizen suits, the court concluded that the definition of solid waste in the statute was broader than that in the RCRA regulations. The import of that was that the deposition of the lead shot was not likely subject to regulatory requirements (i.e., permitting) but was subject to remedial requirements for an "imminent hazard" suit under the statute. Further, without deciding how long was long enough, the court said that the material had been left to accumulate long enough to be considered solid waste (shooting had ceased as of December 31, 1986, and the appeal was decided in June 1993).

In *Long Island Soundkeeper Fund v. New York Athletic Club*, 1996 WL 131863 (S.D.N.Y.), the court followed Connecticut Coastal Fishermen's Assoc. regarding the unpermitted RCRA facility claim using the USEPA position on the regulatory applicability. So, no RCRA permit was required. However, the court held that the trap range was an identifiable source of pollutants (shot and targets) being discharged into U.S. waters, and that further operation was enjoined without an NPDES permit.

In addition, a suit in the U.S. District Court for the Northern District of Illinois (*Stone v. Naperville Park District, et al.*, 38 F. Supp. 2d 651 (N.D. Ill. 1999)) reaffirmed the previous court cases with regard to the RCRA solid waste issue. The Naperville Sportsman's Club operated trap and skeet shooting ranges at a city-owned park with the shotfall zones potentially impacting one or both of two ponds and a ditch connecting them. The lower pond then drains off site. The court dismissed the count for unpermitted RCRA operation and granted summary judgment for Stone regarding the Clean Water Act claim of operating a point source discharge of pollutants to waters of the United States without a permit. The summary judgment enjoined the defendants from resuming trap shooting without an NPDES permit. An NPDES has been issued to the Naperville Park District, and trap shooting has resumed with nontoxic shot.

Therefore, until USEPA and/or the states develop policies on how these materials should be regulated, Illinois EPA feels the ITRC guidance document should be revised to omit references to the regulatory status of the lead shot or contaminated soil at shooting ranges, and how these materials should be regulated. Furthermore, we suggest that the users of the document be directed to contact the regulatory authority for their site when addressing regulatory interpretations on shooting ranges. Illinois EPA cannot support many of the regulatory interpretations presented in the draft document.

Response
We agree that the regulatory status of lead shot can be a complicated regulatory issue, and we will emphasize that users of the document should contact the regulatory authority for their site when addressing regulatory interpretations on shooting ranges. However, we feel that we must provide at least some guidance regarding the regulatory status of lead shot to at least acquaint the user of the document with a rudimentary understanding of the regulatory issues so as to be aware of opportunities for recycling, necessity for waste classification, and other issues regarding the handling of soils containing lead during the remediation of closed shooting ranges.

USEPA has, in fact, developed policy on how lead shot and projectiles should be regulated. The regulatory status of these materials is addressed in Chapter 1 of USEPA's *Best Management Practices for Lead in Outdoor Shooting Ranges*, January 2001. This guidance, developed by USEPA Region 2, was subsequently adopted as national guidance (in a letter from Elizabeth Coxworth, OSWER, and dated October 12, 2001). USEPA sought the support of states on the content of the Best Management Practices Manual. At the time of its printing, 40 states had contacted USEPA and given their concurrence.

Some examples of the portions of the guidance document of concern to Illinois EPA include the following:

2. **Comment**
Sections 3 & 4. When to determine the regulatory classification of the contaminated soil via TCLP.

Response
TCLP testing of contaminated soils should be conducted at the point in the process when remedial options for the site are being identified and evaluated (to determine what soil will require handling as a hazardous waste). TCLP testing is not part of the sampling and analysis conducted to characterize risk; for the risk characterization, total metals analyses are performed. However, in practice, both total metals analyses and initial TCLP tests are often performed at the same time in the investigation process. The decision tree documents the timing for the determination of the regulatory classification of contaminated soils so that proper handling and disposal/reuse of lead-contaminated soil can be accomplished.

3. **Comment**
Section 4.0, Regulatory Requirements, Barriers, and Flexibilities. The regulatory requirements for active ranges may be different than those for closed ranges.

Response

The requirements for remediation should be quite similar. The risk assessment will recognize different exposure scenarios based on use of the site, for example, as a range or other industrial, commercial, or residential use. In addition, in 2003, the Small Arms Firing Range Team of ITRC will develop a management and maintenance guidance document for active ranges.

4. **Comment**

Section 4.1, Classification of Spent Ammunition. This section does very little to expose the problems associated with the regulatory classification of spent ammunition. A major consideration that was not addressed in this section was that a state may consider a material, such as lead shot at an abandoned/closed shooting range and any soil contaminated by it, to be a solid waste because it has been abandoned or discarded (40 CFR 261.2).

Response

Out of necessity we have considered USEPA to be the baseline. Often the determination of "abandoned" is based on previous experience or case history such as those you have previously provided. See Section 4.2, paragraph 2.

5. **Comment**

Section 4.3, State Regulations & Guidance. The BMPs at active ranges may be different from those at closed ranges. In particular, the addition of lime to adjust the pH of the soil may be acceptable at an active range but not at a closed range since its effects are only temporary.

Response

Please see the response to Comment #3 (also see Section 3.3).

6. **Comment**

Section 4.2, Federal Regulations. The document states in Section 4.2 that lead shot at a shooting range meets the definition of a hazardous waste if it is abandoned (or determined to become abandoned). This position is contrary to the stated position of the United States Environmental Protection Agency (USEPA). Since at least 1988, USEPA has taken the position that the discharge of ammunition at shooting ranges does not constitute hazardous waste disposal. The shooting is not a discarding of the rounds. Rather, it is the normal and expected use for which the shells were manufactured and is not a hazardous or solid waste activity falling under RCRA.

Response

The activity itself is not considered a disposal activity, nor is the activity of shooting a hazardous waste management activity; however if through other regulatory processes or investigations it is determined that soils or other material at the surface contain lead in excess of TCLP requirements, then disposal of the contaminated material must be at a hazardous waste disposal facility.

7. **Comment**

Section 4.6, Live Rounds/UXO. The statements in the following paragraph cannot be supported by Illinois EPA:

> …Under 40 CFR 261.23 (6), live rounds are considered characteristically reactive as they are capable of "detonation or explosive reaction if it is subjected to a strong initiating source, or heated under confinement". Also, under 40 CFR 261.23 (7), material is characteristically reactive if "readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure."…

Small arms ammunition does not meet the regulatory definition of unexploded ordnance, or even ordnance and explosive waste. Additionally, small arms ammunition does not meet the definition of a characteristically hazardous waste (D003, 35 Illinois Administrative Code 721.123). In a November 30, 1984 USEPA memorandum (OSWER Directive Number 9443.10-84), Office of Solid Waste Director John H. Skinner stated that based on testing performed by both the Remington Arms Company and the U.S. Army, small-caliber ammunition, up to and including 0.50 (ammunition for the .50 caliber Browning Machine Gun) is not reactive within the meaning of 40 CFR 261.23 (35 Illinois Administrative Code 721.123). Small arms ammunition is typically classified as ORM-D materials for shipping, not explosives.

Traditionally, Illinois EPA has defined UXO as projectiles greater than one-half inch in diameter, with an explosive or incendiary charge of greater than one-quarter ounce (26 United States Code 5845(f)(1)(D)) fired into an impact range that did not function or function properly and completely (i.e., explode or burn) and unfired projectiles that have been discarded prior to being deactivated. This definition does not apply to known inert projectiles and other known inert items, such as small arms ammunition.

Illinois EPA considers this UXO at a facility to meet the definition of a solid waste as identified at 35 Illinois Administrative Code (35 IAC) 721.102(a)(1) because they are discarded materials. The UXO became discarded material 1) when it was abandoned (i.e., the UXO has been abandoned in place when the impact range or target area was deactivated (i.e., closed or transferred) or due to a long, relatively undocumented history of a facility, and 2) when DoD makes the decision to discard/dispose of UXO by detonation or open burning (as identified at 35 IAC 721.102(b)(1) and (2). It is the Illinois EPA's position that UXO remediation efforts are best handled by the experts (i.e., the Department of Defense).

Response
We have removed the regulatory citations classifying live ammunition or UXO and replaced it with language that better represents our intent. Please refer to the new language in Section 4.6.

8. **Comment**

Section 4.7, Soil Recycling. The contaminated soil from a range may not be a "recyclable material."

Response
There are specific guidelines a party must accommodate if they desire that contaminated soil be classified as a recyclable material [see 40 CFR 266.20 (b)].

9. **Comment**

Section 4.8, Transporting or Relocating Range Soil for Reuse as a Backstop on Range Property. Until the USEPA publishes further regulations or interpretations on shooting ranges in the Federal Register, the decision of whether to require testing soil generated from the reclamation of lead shot for hazardous waste characteristics before reuse needs to be left up to the states. It will likely depend on whether the range is active or closed and if the state views the contaminated soil as a solid waste. The flow chart (Figure 1-1) should also be revised to reflect this important issue.

Response

Active ranges are a separate issue addressed by clear guidance from USEPA as referenced. It should be noted that the focus of this document is removal of contaminated soils at closed ranges. For closed ranges, states should always be consulted regarding their authorities and guidance. Within this, the states have the ability to be more stringent than USEPA within a delegated authorization. It is our team's understanding that USEPA is in the process of seriously considering the on-site reuse of berm soils as construction material, and the ITRC Small Arms Firing Range Team supports this. However, it is our understanding that, even though there are individuals within USEPA and the states that support the reuse of berm material to construct berms off site, it is of serious concern and may not be supported agencywide.

Our decision tree has been clarified regarding definition of construction material (i.e., intended for active ranges on site) in response to this comment. The decision tree supports what our team considers the baseline but does not intend to deplete states' authority to be more stringent.

10. **Comment**

Section 4.8, Transporting or Relocating Range Soil for Reuse as a Backstop on Range Property. The statement that it is USEPA's position that soil generated from the reclamation of lead shot is a "construction material" and can be used off site (without even testing to determine if it is a hazardous waste) needs to be followed up by referencing the specific document in which this position was published (e.g., the Federal Register). A policy memorandum, or general correspondence from USEPA on the issue may not be sufficient for a state to accept this position.

Response

Please see response to previous comment.

11. **Comment**

Section 4.8, Transporting or Relocating Range Soil for Reuse as a Backstop on Range Property. Taking contaminated soil off site to another facility may require the receiving site to be permitted to receive nonhazardous or hazardous waste. This may be the case even if the site is a range adjacent to the generating site and owned by the same person.

Response

Please see response to Comment #9.

Illinois Comments on Specific Sections

12. **Comment**

Figure 1-1, Flow Chart. The flow chart indicates that the first step in the process is to determine the postremediation land use and refers to Section 2.7.2 of the document. However, Section 2.7.2 does not appear to include any discussion on determining whether the range will remain active or if it will be closed. This is an important distinction that should be addressed in the document. Is Section 2.7.2 the correct reference for this part of the flow chart? Finally, since this is the first step of the flow chart, it seems like it should be addressed before site characterization (Section 2.0) in the document.

Response

The team determined that the term "active" indicated a range would remain a range and appropriate environmental management plans would be implemented according to USEPA's BMP. Otherwise, land use would define exposure scenarios described (as an example) in Figure 2.5 of the document. Section 2.7 describes the process of assessing the risk associated with a change in the land use at a site.

13. **Comment**

Section 4.2, Federal Regulations & Guidance. This section refers to the Military Munitions Rule (MMR). The ITRC guidance document should be revised to note that the MMR does not include shooting ranges that are closed or closing. Specifically, USEPA realized the regulatory requirements for closed ranges were different from those at active ones and addressed this point on pages 6631 and 6632 in the preamble to the MMR [FR Vol. 62, No. 29. February 12, 1997]. In fact, page 6631 states that USEPA did not generally intend to include range clearance activities at transferring or closed ranges within the scope of the MMR. Page 6632 goes on to state that used or fired munitions that are recovered and then treated on range at a closed or transferred range would be a solid waste potentially subject to RCRA Subtitle C regulations. It further states that this aspect of the rule (the MMR) is being postponed, along with the closed and transferred aspect discussed in Section H of the preamble, because these issues are being addressed under DoD's range rule.

Response

The comment that the Military Munitions Rule does not apply to closed ranges is correct. The document is amended to clarify the relevance of the MMR to range remediation

14. **Comment**

Section 4.3, State Regulations & Guidance. This section focuses on the use of best management practices (BMPs) to control storm water from ranges. It needs to be revised to include a broader spectrum of issues that individual states may face during the remediation of a shooting range.

Response

The team agrees that during remediation of small arms firing ranges there may be a variety of issues encountered; however, we feel that the decision tree gives the general sequence of the major decisions, which should be made during the course of removing the hazard from the site.

The section you referenced is a description of a state's baseline authority to control discharges from an operating site.

15. **Comment**

Section 4.8, Transporting or Relocating Range Soil for Reuse as a Backstop on Range Property. The first paragraph in this section states that soil generated from the reclamation of lead shot at a range that is closing may be placed back on the range (or elsewhere on the range property) without testing the soil for hazardous waste characteristics. It also states that this position is consistent with the MMR. This statement appears to be in conflict with the preamble of the MMR (62 FR 6631-6632) and USEPA's *Best Management Practices for Lead at Outdoor Shooting Ranges* (EPA-920-B-01-011).

Response

It was not the intent of the team to imply that soils could be placed back on the closed range without proper testing. The guidance states "it may be possible and desirable to reuse soils from the backstop of a range that is being closed to construct a new berm or rebuild an existing berm located in **another area of the range's property**"[emphasis added]. That is, soil would not be placed back on the closed range but rather reused on an active range on the same property or at the same facility. To clarify, the guidance will replace the term "range property" in the above sentence with "same property" or facility property.

The team agrees that the statement, "This position is consistent with the Military Munitions Rule" is misleading. It was intended to draw a comparison between the allowed relocation of soils at active ranges, permitted under the MMR, with the reuse of soils from a former range at an active range. Because of the confusion created by this statement, however, it will be dropped from the document.

16. **Comment**

Section 5.4, Soil Stabilization. This section should be revised to include a discussion regarding the stabilization/solidification of contaminated soil with lime. Specifically, it is our understanding that treating contaminated range soils with lime is generally considered to be a temporary adjustment to the soil and should be done only at active ranges, not as part of a final remediation at a range that is going to be closed.

Response

Please review Section 3.3, Soil Stabilization, for the requirements to design and test the soil's ability to be maintained and an applicable range of pH to prevent dissolution of lead from the soil.

17. **Comment**

Section 7.0, References. Does not include the USEPA guidance *Best Management Practices for Lead at Outdoor Shooting Ranges*, EPA-902-B-01-001, January 2001. If this guidance was used in the preparation of this ITRC document, it needs to be referenced in this section. If it was not used, ITRC should provide the reasoning for omitting it from consideration.

Response
It has since been included.

New York

18. **Comment**
I [New York] have looked at the document, mostly the Executive Summary and Section 6 and have a few comments. The biggest one is that while some of this may be of value for commercial ranges, very little of this information would be of use to the hundreds of shooting club ranges that exist in New York and, I am sure, everywhere else. Lead at these ranges is an issue from time to time, but the sites generally don't rise to a level of concern where they would trigger a remediation requirement. Further, many of these ranges have annual budgets of a few thousand dollars, and the idea that they would use any kind of treatment like soil washing is not well conceived. The material that is in Section 6, which I guess you are calling "issues" are mostly comments on different topics (e.g., current models use residential or industrial exposure criteria, but BRAC bases are recreational areas that don't fit into either category). I think you should take a hard look and separate the issues from the commentary.

Response
You are correct in your assessment that this only applies to ranges under remediation. We intentionally excluded management of operating ranges from this document.

I'll [New York] list a few specific comments. It is not a complete review, but these are a few things that jumped out:

19. **Comment**
<u>Page 65, 1st bullet under "Technical Issues."</u> It is an incomplete sentence. What should be done with the more thorough understanding?

Response
The statement is misleading and has been deleted from the text.

20. **Comment**
<u>Page 60, 1st bullet under "Soil Washing."</u> New York would have a regulatory impediment with the use of "on-site capability." Except for screening, analysis would have to be done by a certified lab.

Response
We have added the following sentence to the end of the bullet. "Some states may require certified labs to be used for these tests."

21. **Comment**
<u>Section 6.6.1, Soil Washing</u>. The last two bullets are identical.

Response
The 7th bullet has been deleted.

22. **Comment**
Page 67, 3rd bullet. This bullet implies (as do several others) that the site is contaminated with more than just lead from a firing range. If this is the case, the document should not apply or at least should identify the complete remedy.

Response
This section has since been rewritten; however, as the document clearly describes, the focus is on lead in soils. We have identified other related contaminants in Table 1-1. This comment from a stakeholder expresses interest in PRPs' paying attention to mixed contaminants resulting from multiple use of a site. Table 1-1 has been incorporated to document that fact; however, to effectively cover an issue without anticipating every scenario caused the team to focus on lead primarily (normally, the cleanup driver), again noting that other contaminants associated with ammunition and the activity of shooting should be recognized in the site investigation.

23. **Comment**
I can answer the question in your e-mail about how soil that has residual lead contamination should be used after remediation is complete. We would allow the soil to be used on the range for building a new berm (backstop) or another construction-type project. If the soil did not fail TCLP, we probably could issue a beneficial use determination (BUD) to allow it to be used to build a berm on another site, but it would have to go through the process contained in Part 360 of our regulations (6NYCRR360, available on our Web site) because otherwise it would be regulated as a solid waste.

Response
Thank you for the information.

24. **Comment**
The table of contents doesn't indicate section numbers or list any tables, figures, or appendices. It's difficult to get an overall picture of the contents.

Response
The automated table of contents and associated numbers will be in subsequent versions.

25. **Comment**
Reference to USEPA's January 2001 BMPs for Lead appears in the Executive Summary and Introduction but doesn't get listed in Reference section. Another reference to same document should be fixed (see page 48, third paragraph).

Response
Thank you for pointing out our omission. It has been added.

26. **Comment**
Format tables consistently. Sometimes title appears at top of the table, others at bottom.

Response
Thank you for the excellent formatting suggestion. All figure descriptions have been moved to the bottom of each figure.

27. **Comment**
Consider providing hot links to go to reference documents.

Response
We will consider hot links. Please attend the upcoming Internet training on this document. It contains a links page providing these hotlinks where available.

Ohio

28. **Comment**

We agree with ITRC's Small Arms Firing Range Team position concerning reusing the soil for a backstop (after the lead is reclaimed) at ranges that are either active or inactive. We define inactive ranges as those ranges not currently being used but planned for use in the future. We also agree with comments provided by the state of Florida, which state that reclaiming lead as part of routine range maintenance, and then reusing the soil on the same area of concern (AoC) (without testing) does not constitute a hazardous waste management activity.

However, we do not agree with the ITRC Small Arms Firing Range Team's position that lead-contaminated backstop soil can be moved out of the contiguous AoC. We agree with Florida's comments that this contaminated soil becomes "discarded material" within the meaning of 40 CFR 261.2(a)(1), because it is "used in a manner constituting disposal" and it is "reclaimed." Therefore, the removed backstop soil would be subject to hazardous waste management regulations, including the requirement to make a hazardous waste determination, manifesting, and land disposal restrictions that prohibit "placement" of hazardous waste on the ground unless it meets the appropriate treatment standards set forth in 40 CFR Part 268. In addition to regulatory prohibition against this activity, we also think that it is a bad management practice to move contaminated soil away from AoCs because of the potential for the contaminated material to be mismanaged. This concern becomes even greater if the soil is allowed to be moved to off-property locations.

We also feel that the ITRC Small Arms Firing Range Team should discuss that, if the range is closed and no longer used (either by the current owner or future owner), the site (including the soils) should be characterized and, if necessary, remediated to appropriate standards for the intended reuse of the site. Reclaiming the lead and replacing the soil without characterization should be an option for only those ranges that will continue to be used as a range (including inactive ranges) and should not be an option for closed ranges.

Response

During the comment period we have received a number of states and even USEPA expressing concern that off-site reuse is likely not a position USEPA will take. This being the case, along with the strong comments from states against this position, the team has reconsidered automatically supporting a position with opposition from several states. The team will continue to investigate the possibility of alternative language conveying the value of on-site and off-site berm reuse. Please see response to Comment #15.

29. **Comment**

In the document, it states that, due to DoD range management practices, some small arms ranges may be located in areas where unexploded ordnance and live rounds may be located. In Section 4.6, it also goes on to state that addressing UXO as part of range management is not a problem, since soil washing would safely detonate this material. There are many different types and sizes of munitions that the military has used, depending on the range. We feel that though it may be safe to handle small rounds with soil washing, there are larger and more dangerous rounds where such practices would not be considered safe. Therefore, we feel that these ranges with potential for UXO or live munitions should be deferred to an explosives and ordnance disposal expert to determine the safe method for clearing the range.

In addition, at sites with UXO or partially detonated material, there is a high potential that these sites will be contaminated with explosives. The document needs to recognize this, since it currently states that explosives contamination is not expected at ranges due to the complete detonation during firing.

Response
We have added language in Section 4.6 as follows: "The intent of this section is to emphasize that while the focus of this document is dealing with small arms firing ranges, experience has shown that unexpected UXO is occasionally present even if there are no historic records indicating large arms use or storage at the site. If physical evidence or historical records indicate the presence of UXO, an appropriate response should be conducted by an explosives or munitions response specialist prior to conducting any required intrusive activities at a closed range. If UXO is present, a second sweep/clearance should be performed in the feed pile just prior to treatment. The process plant operators should also be trained in UXO recognition, with appropriate shutdown and notification procedures in place in the unlikely event UXO makes its way into the treatment plant."

30. **Comment**
The document should devote as much emphasis on the characterization of the small arms firing range (SAFR) sites as it does to the various remedial technologies. Proper investigation and characterization of the SAFRs will lead to the proper selection and implementation of remedial technologies.

Response
The team believes that the aspects unique to characterizing small arms firing ranges have been included in this document. Characterization as a technique of its own has been repeatedly addressed. Please go to www.itrcweb.org, "Guidance Documents," and click on "Accelerated Site Characterization." ITRC also has a UXO Team addressing the much larger issue of UXO separately, and both documents will reference the other when completed.

31. **Comment**
The document seems to support the use of institutional controls (recreational use) as a means to vary from cleaning up the range to either residential or commercial/industrial standards (400 ppm lead and 1000 ppm lead). Though cleanup standards for sites should be based on future use, there are other considerations (necessary funding for long-term monitoring and enforcement) that should be considered as part of this evaluation. If the range is small, it may actually be more cost- effective to remediate the site to more stringent standards than the use would require so that institutional controls would no longer be required.

Response
Conditions at the site and negotiations among the parties always play a role in the final decision. It is not the team's standard to alter that.

32. **Comment**
The entire document needs to be run through spell check as well as a grammar/punctuation check.

Response
This will be done and is occurring again during the preconcurrence review. We hope the misspelling and punctuation errors have not severely affected your review.

33. **Comment**
The risk assessment section recommends following *Risk Assessment Guidance for Superfund* (USEPA, 1989) and *Ecological Risk Assessment Guidance for Superfund* (ERAGS, 1997). This is standard USEPA guidance for conducting baseline risk assessment. The risk assessment discussion basically is a repetition of the USEPA guidance and process. The information provided in this guidance document would better serve the user by briefly summarizing the USEPA guidance and allowing the reader to refer to the USEPA guidance for more detailed discussion and focusing on specific details of the risk assessment that are common to small arms firing ranges. One common hurdle in the risk assessment process is obtaining consistency. Consistency is very important in the risk assessment process and allows a degree of comparability among sites and in risk management and remedial decision making. Utilizing a standardized process will promote consistency and accelerate the evaluation process. When assessing risk at small arms firing ranges and developing exposure pathways, many characteristics and receptor exposures will be similar, simply as a result of common land uses. On that note, we suggest developing a standard list of receptors and exposure assumptions that reflect RME exposures that are common and reasonable for decision-making purposes. In addition to defining a standard set of receptors, exposure assumptions, and exposure pathways, we recommend developing site-specific preliminary remediation goals (PRGs) based on the standard assumptions/receptors/exposure pathways determined to be common at small arms firing ranges. Another option is to specify an existing source of PRGs, such as the USEPA Region 9 PRGs, that is acceptable for screening purposes in the risk assessment. These factors are the practical considerations of the risk assessment, and nailing this detail down would facilitate the development of risk assessment on small arms firing ranges and promote consistency in the evaluations and remedial decision making.

Response
Your recommendations have been addressed in revising the document.

34. **Comment**
The information provided in this guidance document on ecological risk assessment is a repetition of the information already provided in the USEPA *Ecological Risk Assessment for Superfund* guidance document. Providing default exposure assumptions and generic receptors for the ecological risk assessment process would help promote consistency among sites.

Response
Ecological risk assessments are very site-specific, so it is impractical to provide default assumptions and generic receptors. Risk assessment references are provided in the appendix. Also please see the response in Comment #33.

35. **Comment**

Section 1, Introduction. This guidance document over-generalizes the type of contamination that may be found on these types of sites and suggests limiting characterization primarily to lead, which is not acceptable. Some sites may have UXO issues to manage during the characterization and remediation of these sites, which should be noted in this guidance. The determination of the nature of contamination, in addition to the determination of the extent of contamination should be included in the bulleted items listed in this section. Nature of contamination should not be limited to only lead and should include all potential types of contaminants such as TAL metals, explosives, propellants, nitrocellulose, UXOs, and dioxin, if appropriate. Also, the bullets should mention that the BRA is designed to assist risk management and remedial decision making. This clarifies to the public how the information from this BRA is used in remedial investigations. In addition, a discussion should be added about the recent development of green ammunition, and whether or not this type of munitions would cause any contamination or differences in the range management practices described in this document.

Response

Please see Section 2.3, Rifle/Handgun Firing Range Layouts, for the team's discussion of the issue of UXO. Also please note the reference to the ITRC Web site, taking the reader to the ITRC's UXO Team Web page.

The team noted the contaminants related to the ammunition used at small arms firing ranges as well as the material used in the activity of shooting. See Table 1-1. In studies to date, lead has been the primary driver (CoC).

This document addresses remediation of ranges. ITRC is considering a team to research the issue of range management as a follow-up to this document in future years. Green ammunition would be a topic for discussion at that time.

36. **Comment**

Section 1.0 (page 1), Table 1-1. This table should be expanded to include lead as a potential contaminant that may be found at small arms firing ranges, or specify that this table solely lists co-contaminants of lead.

Response

Good point. It has been included.

37. **Comment**

Section 1.0, last paragraph (page 2). Why was the EP Toxicity Test used in 1995, given that TCLP testing was already in use?

Response

The following paragraph does not specify that the EP Toxicity Test was used rather then the accepted TCLP. In fact, Baer used the TCLP test: "The disk-like, flying targets used at shotgun ranges contain PAHs. However, Baer (1995) found that the targets did not exhibit the characteristics of toxicity as determined by an USEPA toxicity test even though they contained high levels of PAHs. The state of Connecticut accepted these findings and treated the targets at the site as solid rather than hazardous wastes."

38. **Comment**
Figure 1.1, Decision Tree. The first step in the process is to determine the postremediation land use. Given this, the Army and other services must become more proactive in working with regulators to determine future land use, writing Land Use controls into Records of Decision/Decision Documents, etc., otherwise the formulation of this guidance is essentially an exercise in futility.

Response
You are correct.

39. **Comment**
Appendix F, Section 2b, Components of a Baseline Risk Assessment, Exposure Assessment. It would be helpful to include a detailed discussion of the importance of determining current and future land use at the site, prior to developing exposure assumptions and the role that this information plays in the development of these exposure assumptions. It is equally important to discuss the importance of having a mechanism in place to ensure future use restrictions and institutional controls if the future use of the site is restricted. In the state of Ohio, we assess future risk as unrestricted (a.k.a. residential) exposure. In addition, it would be helpful to have a list of default receptors and exposure assumptions that are applicable to most small arms firing range sites. This would help standardize the assessments at these sites and instill consistency in the evaluation.

Response
Please our response to Comment #30. Your comments are very thoughtful and have application to every remediation effort, not only lead and related compounds at small arms firing ranges.

40. **Comment**
Appendix F, Section 2c, Components of a BRA, Toxicity Assessment. This section/discussion should provide a list of acceptable sources for obtaining information on toxicity for use in a BRA. Many sources of this information are available, and providing an acceptable list of sources helps standardize the process and promotes consistency. For instance, Ohio EPA recommends IRIS, HEAST, NCEA, etc.

Response
This level of detail should be dealt with on a site-specific basis.

41. **Comment**
Appendix F, Section 2d, Components of a BRA, Risk Characterization. This section should include a discussion of how to assess exposure to multiple contaminants via multiple routes and pathways.

Response
The procedure is included in Appendix F.

42. **Comment**

Appendix F, Section 2e, Components of BRA, Lead. A lot of detail is provided for lead, and little information is discussed on other contaminants of potential concern (CoPCs), such as arsenic, copper, chromium, etc. This section should be expanded to include a brief discussion of each COPC. In addition, this guidance document should specify the USEPA goals of 400 ppm for residential/unrestricted exposure sites and 1000 ppm for industrial exposure sites.

Response

The team considered lead to be the driver in most risk assessments conducted at small arms firing ranges. Including multiple compounds or cumulative risk is a risk assessment issue applicable to every remediation activity regardless of the contaminant driver. See Section 2.7. The narrative is not simply discussing two exposure pathways—all options are discussed in the document in detail.

43. **Comment**

Section 2.5, Fate & Transport Considerations. The text should be revised to read: "....about lead dissolving into the surface or groundwater, entering the soils or being ingested by birds or other wildlife."

Response

This section has been revised, and this sentence no longer appears in the text.

44. **Comment**

Section 2.6, Sample Collection & Analysis. The text in the first paragraph indicates that the site use and history will provide information regarding volumes and types of ammunition used and indicate the likely CoCs at the range. The readily obtained historical information is not always accurate and adequate. At this stage of the process, it would be inadvisable to prematurely limit the analytical testing suite.

Response

Review of the historical information is just a first step. Section 2.6 continues to suggest a walkover of the site to confirm what the site history might reveal and document addition indications of contamination distribution. This iterative and systematic process leads the investigation, rather than attempting to blanket the site with sample locations and analyzing the aliquots for a suite of parameters unrelated to the use of the site.

45. **Comment**

Section 2.6.2. The third bullet in this section indicates that background concentrations of CoCs should be determined. The determination of background is always a critical and much-debated issue. As such, there should be a statement in the text that regulatory acceptance/concurrence/approval of how background is determined, how many samples are needed, what statistical tests are utilized, etc. is necessary. This point also goes back to general comment #3, which indicates that the characterization portion of this entire document is underdeveloped.

Response

The determination of background is not an issue specific to small arms firing ranges nor to contaminants associated with ammunition and targets. It is a larger debate surrounding the acceptability of background sampling location, depth, analytical methods, natural occurring or anthropogenic, statistical analysis, and presentation of the data. We have included the configuration used to design a sampling program on the contaminated areas, including the depth interval in the shadow of the firing pattern. See Section 2.6.2.

46. **Comment**

Section 2.6.2.1, Use of Field Screening. The text should be revised (first sentence) to indicate that field screening using XRF may be one way to define boundaries of the area, etc. Given our experience at Ravenna Army Ammunition Plant, we have not had much good fortune in the use of XRF (both in-situ and ex-situ techniques). The position that we have taken with respect to the use of XRF at the RVAAP is that it is not accurate or reliable enough to guide field investigations or to conduct soil-removal activities.

Response

We have footnoted the fact that this method is sensitive to particle size and that the analysis should be confirmed with lab analysis. We have also replaced "can" with your suggested term "may."

47. **Comment**

Section 2.6.3. With respect to the use of composite samples for metals analyses, we use a similar technique for explosives-contamination determination. However, it would need to be up to the appropriate regulatory agency to determine if composited results could be used for risk assessment purposes.

Response

Yes, it is always up to the state agency, if it has a procedure previously developed. This is not intended to circumvent existing procedures, only add to the tools available to users.

48. **Comment**

Section 2.7.4, Measuring Bioavailability for Determining Risk. Second paragraph implies that lead, arsenic, and copper are the only contaminants evaluated in the risk assessment. All contaminants of potential concern, where there is complete exposure pathways for a receptor and where those CoPCs exceed screening levels, must be evaluated in the risk assessment, and the focus should be broadened beyond lead, arsenic, or copper.

Response

We agree that bioavailability of all the compounds is of concern. All potential CoCs will be included in the discussion.

49. **Comment**

Sections 2.7.4, Measuring Bioavailability for Determining Risk. These sections provide a great amount of detail on the toxicity and bioavailability of lead and, to a much lesser extent, arsenic. This information is not necessary in this detail. From a risk assessor perspective, information such as default assumptions for the percent uptake, BAF, and other input parameters for evaluating risks quantitatively in the risk assessment would be more useful information expected in a guidance document. This would also lead to consistency in the risk process.

Response
The bioavailability of lead is discussed as an example of the current state of the art for evaluating risk. This is appropriate since lead is the primary CoC at SAFRs. Additional discussion of effective soil-stabilization techniques with regard to bioavailability is presented in Section 3.3.3.

50. **Comment**
Section 2.7, Risk Assessment Variability. Ohio EPA has written draft guidance on ecological risk assessment that is soon to be released. This guidance is based on the state of Oregon's ecological risk guidance. Ohio recommends that all sites first conduct a level 1 scoping assessment to determine if ecological receptors, habitat, land use, sensitive environments, important ecological resources are present at the site. This information will help determine if further eco assessment is necessary. For instance, if contamination is present but not any important ecological resources, receptors, or sensitive environments, then ecological exposure pathway is not completed and does not occur.

Response
The risk assessment section will be modified to add the suggestion that individual states may have guidance, which should be consulted prior to conducting a risk assessment

51. **Comment**
Section 2.7, Components of a Risk Assessment. The assessment of bioavailability should be part of the toxicity assessment. We suggest developing a standard list of receptors and exposure assumptions that reflect RME exposures that are common and reasonable for decision-making purposes. In addition to defining a standard set of receptors, exposure assumptions, and exposure pathways, we recommend developing site-specific preliminary remediation goals (PRGs) based on the standard assumptions/receptors/exposure pathways determined to be common at small arms firing ranges. Another option is to specify an existing source of PRGs, such as the USEPA's Region 9 PRGs, that is acceptable for screening purposes in the risk assessment. This should be done for both the human health and ecological risk assessments.

Response
The risk assessment section (including bioavailability) will be edited to present only the relevant details and references. It is beyond the scope of this document to develop PRGs for SAFRs; however, reference to existing sources of PRGs, such as USEPA's Region 3 RBC tables and Region 9 PRG tables, will be made.

52. **Comment**
Section 2.7.1, Contaminant Identification. Compounds such as nitrites and nitrates may be important to sample for and evaluate, especially in groundwater where blue baby syndrome can occur as a result of exposure. This may be an important consideration for sites where UXO or explosives are an issue. In addition, the document should specify that site-specific background

for inorganics be determined and used for screening, along with risk-based screening values for the selection of CoPCs.

Response

Please go to www.itrcweb.org and to the Guidance Document section. Locate the box labeled "In Situ Biodenitrification," which contains a technology overview of in situ biodenitrification and an additional document, *Systematic Approach to In Situ Bioremediation of Groundwater, including Decision Trees for Nitrates, Carbon Tetrachloride and Perchlorate*, which addresses nitrate contamination, its sources, and additional health consequences of nitrate contamination other than blue baby syndrome.

Additionally, UXO is included to raise awareness. This document focuses on small arms firing range issues. UXO is better addressed in the UXO section of the ITRC Guidance Document section at the Web location identified previously.

53. **Comment**

Section 2.7, Contaminant Identification. With respect to contaminant identification, the conclusion indicates that the analytical suite should be mainly focused on metal, particularly lead and copper. The analytical suite should not be prematurely limited based upon the potential for other CoCs such as PAHs, explosives, and propellants. 100% of the samples would not need to be analyzed for a full suite, but a certain percentage should be in order to ensure that the range is properly characterized. Analyzing the samples for TAL metals, instead of just lead and copper, would not substantially increase the price. Given the constituents listed in Table 1.1 in this document, then TAL analysis is warranted. In addition, since tin is not on the TAL list, it would need to be added as an analyte.

Response

The team recommended that a suite of parameters for characterizing a small arms firing range would include those in Table 1-1. PRPs and oversight agencies may require additional parameters according to their assumptions and knowledge of the site.

54. **Comment**

Appendix F, Section 3a, Application of the BRA Process to Small Arms Ranges, Contaminant Identification. The last sentence of the first paragraph states that the analytical suite can be focused on lead and copper. We disagree with this statement, as previously noted in [in Comment #53 above]. TAL metals should be analyzed for initially at sites, since other metals such as arsenic, copper, chromium, zinc, UXO, explosives, nitrocellulose, etc. may potentially be present at these sites. After the initial investigation and the initial analytical results are evaluated, further analytical testing may be focused on certain contaminants that exceed screening criteria.

Response

See response to Comment #53. We should also note that team members have never found evidence of chromium at a SAFR site.

55. **Comment**

Appendix F, Section 3b, Application of the BRA Process to Small Arms Ranges, Exposure Assessment. Second paragraph states that site visitors are not allowed near the area where the backstop/berm is, thus eliminating exposure. Unless there is a mechanism to monitor and enforce this restriction, potential exposure could occur to site trespassers, site workers, maintenance workers, construction workers, and other users of the site. Therefore, the assumption that current use will not result in exposure must be substantiated and supported by specific details to demonstrate that this is true for all sites of this type.

Response

Our document states, "If the range is to continue to be used, metallic deposition in the backstop/berm area will continue. The only human receptors will be site workers, who are covered by the exposure standards of the Occupational Safety and Health Administration (OSHA). For safety, site visitors are not allowed near the backstop/berm area, thus eliminating their exposure. Ecological concerns are addressed by the nature of the range operation."

Trespassers are part of the undesirable behavior none of us can control or monitor. Site workers, maintenance workers, construction workers are covered under OSHA requirements as stated in the text, and on-site users are restricted to the shooting area.

56. **Comment**

Table in Section 3.1. The table should be revised to clearly indicate that the three metals listed are not the only RCRA TCLP requirements.

Response

The constituents listed are those related to the firing range activity. If for some reason other TCLP parameters and their concentration factors are considered present, they should be included. We focus on those parameters related to the firing range activity. Other parameters would be related to former use other than shooting ranges or off-site contamination.

57. **Comment**

Section 4.6, Small Arms Rounds. Wet screening and water-based density separation processes are referenced. These techniques should be described in more detail at some place in the guidance document.

Response

Please refer to Section 3.2, Soil Washing/Particle Separation.

58. **Comment**

Section 4.8, Transporting or Relocating Range Soil for Reuse as a Backstop on Range Property. This section is unacceptable. See general comment #1. In addition, this section completely contradicts the first paragraph in Section 5.0 on page 47.

Response

Please see our response to Comment #28.

59. **Comment**
Section 5.1, second paragraph, page 47. This paragraph seems to support the use of compositing for treating metals-contaminated soil. Though explosives can be degraded by compositing, metals cannot be degraded by this method. Please clarify why this is proposed as a technology for metals-contaminated soil.

Response
Our intent in this section is to discuss compositing samples to obtain a representative concentration of contaminant in the material.

60. **Comment**
Section 5.4, page 53, the last paragraph. Additional text should be added to the guidance document that supports/substantiates the sampling frequency of 250 cu yd and 500 cu yd.

Response
The sampling frequency is based upon the daily throughput of the operation for current technologies.

61. **Comment**
Section 6.0 needs to be revised based upon general comment #28 and specific comment #58.

Response
We agree. See response to Comment #15.

Pennsylvania

62. **Comment**

There are many instances of incorrect punctuation as well as several typographical errors. Wording in a number of places is difficult to understand and could be modified to make the concepts more understandable. It is assumed that the document will be proofread several more times to catch these areas.

Response

Proofreading is taking place during the preconcurrence review.

63. **Comment**

<u>Section 2.2, page 7 (at the top)</u>. Shouldn't the word "parallel" be "perpendicular?"

Response

"Parallel" is used correctly. The firing line is perpendicular to the line of fire, and the targets are aligned perpendicular to the line of fire.

64. **Comment**

<u>Section 2.4</u>. The word "injected" should be "ingested."

Response

This section has been revised, and the words "injected" (or "ingested") no longer appear.

65. **Comment**

<u>Section 6.6.1, Soil Washing</u>. The 6th and 7th bullets under "Soil Washing" are identical. One should be deleted.

Response

The correction has been made.

66. **Comment**

<u>Section 2.6.2.2, page 17</u>. The last sentence of the third bulleted paragraph reads: "Soil-lead dissolution capacity may increase as a function of decreasing soil grain size due to the increase in particle surface exposed." This seems misleading. It could be restated, "Soil-lead sorption capacity may increase as a function of decreasing soil grain size due to the increase in particle surface exposed." This is simply because an increase in surface area provides more sorption sites. The sentence doesn't seem to have any usefulness.

Response

You are correct. The statement has been removed, and the section rewritten. .

67. **Comment**

<u>Section 4.8, Transporting Range Soil for Reuse as a Backstop on Range Property</u>. The dilemma of using backstop soil from one site at another site is mentioned. The caveat or provision that individual states should be contacted for approval prior to such action seems sufficient. This

would allow such actions to be addressed on a case-by-case basis. Pennsylvania has been grappling with this concept (transporting contaminated soil from a remediation site to another location, the “Safe Fill Policy”) for several years. It has yet to be resolved.

Response
Thank you.

68. **Comment**
Decision Tree, page 4. Remediation in Pennsylvania is voluntary; however, if liability relief is being sought (i.e., if the site is to be deemed “officially” remediated), the remediation must follow what we will call the promulgated “cleanup standards.” (We have several cleanup standards.)

Therefore, for two of the cleanup goals on the decision tree (Disposal and Soil Reuse), an additional green diamond (worded “Does total Pb meet cleanup level?”) would be necessary. For the Disposal goal, the “yes” arrow coming from the existing green diamond would go to one of these two green diamonds. An answer of “yes” to that question would allow the soil to remain on site. An answer of “no” would require off-site disposal.

For the Soil Reuse goal, the arrow going from “Asphalt Emulsion Treatment” would go to the other of these two green diamonds. The Construction Material goal implies that liability would not be sought because the soil could remain on site as berm/backstop construction material.

Response
Does total lead meet cleanup level? – Disposal option. According to the referenced section, direct disposal is “Dig and Haul” (Section 3.1). If it met the cleanup standards, it would not have initially been excavated; therefore, the flow path applies only to the requirements for off-site disposal.

Does lead meet cleanup standards? – Soil Reuse. We disagree because the remaining lead in the soils is stabilized and has demonstrated through the TCLP and SPLP tests that it will remain so. There is no longer any need to dispose of the material as a hazardous waste, and it cannot be used as construction material in a berm. It is a paving product.

69. **Comment**
Of course, if liability protection is not being sought, remediation may be conducted apart from the cleanup standards, and the state would neither approve nor disapprove. No action would be taken by the state unless harm to human health or the environment was occurring or was likely to occur.

Response
Thank you.

Florida

70. **Comment**

Section 6.0, Issues, Concerns, and Recommendations. I have very grave concerns about the following proposed language:

"It is the ITRC Small Arms Team's position that range soil from a former backstop may also be reused, following lead reclamation, for constructing or rebuilding a backstop at a location that is not on the range property. Reclaimers should apply standard BMPs, mentioned in USEPA's *BMP for Lead at Outdoor Shooting Ranges*, to separate the lead from soil. Individual states may impose additional requirements for transportation, documentation, and approvals; however, state regulators should be consulted prior to transporting range soils to a property that is not the same as or adjacent to and under the same ownership as the property where the soils originated."

This language misrepresents or misunderstands the regulatory status of soil contaminated with lead shot under the federal Resource Conservation and Recovery Act (RCRA) and has serious implications for the hazardous waste management program adopted by the state of Florida to operate in lieu of RCRA.

Lead shot falling to the ground at a shooting range as the result of ammunition discharge is not regulated as hazardous waste disposal. (See letter, Sylvia K. Lowrance, USEPA, to Jane Magee, state of Indiana, September 6, 1988.)

When a backstop is in use, and lead is being reclaimed as part of standard or routine range maintenance, the recovered lead is considered "scrap metal" pursuant to 40 CFR 261.6(a)(3)(ii) and, therefore, excluded from most RCRA regulations. (See Memo, Jeff Hannapel, USEPA Office of Solid Waste, to Duncan Campbell, USEPA Region 5, March 13, 1997.) In addition, USEPA has made it clear that the range clearing principles of the Military Munitions Rule (40 CFR Part 266, Subpart M) apply as well to nonmilitary ranges. (See letter, Elizabeth Cotsworth, USEPA, to John P. Cahill, state of New York, April 29, 1997.) Therefore, the collection of fired bullets, including those that contain lead, and replacing the soil or other material separated from the lead bullets is not a hazardous waste management activity. (See 62 Federal Register 6631, February 12, 1997.)

Even if the backstop soil were considered to be toxic hazardous waste because it contains a lead concentration greater than 5 mg/l, the material could be properly managed within the "area of contamination" or "AoC," defined as the contaminated area contiguous to the existing backstop, because "movement of media contaminated by hazardous wastes within an area of contamination does not typically trigger RCRA requirements." (See letter, Michael Shapiro, USEPA, to Norman Nosenchuck, state of New York, March 25, 1996.)

However, when lead-contaminated backstop soil is moved out of the contiguous AoC to build a backstop at another location, whether on site or off site, the contaminated soil becomes a "discarded material" within the meaning of 40 CFR 261.2(a)(1) because it is "used in a manner constituting disposal" and it is "reclaimed." Therefore, the removed backstop soil would be subject to hazardous waste management regulations, including the requirement to make a hazardous waste determination, manifesting, and land disposal restrictions that prohibit "placement" of hazardous waste on the ground unless it meets the appropriate treatment standards set forth in 40 CFR Part 268. (See EPA-902-B-01-001 *Best Management Practices for Lead at Outdoor Shooting Ranges*, USEPA Region 2, January 2001, pages 1–8; *Best Management Practices for Environmental Stewardship of Florida Shooting Ranges*, Florida Department of Environmental Protection, Hazardous Waste Compliance Assistance Program, June 2002, page 40.)

Soil that exhibits the hazardous characteristic of toxicity for lead should not be moved off site to build a new backstop. This is a practice that RCRA was designed to prohibit, because the potential for environmental contamination is too great.

In conclusion, I recommend that the Florida Department of Environmental Protection point out the legal infirmity of ITRC's proposal.

Response

ITRC appreciates Florida's full participation in the Small Arms Firing Range Team while researching, drafting, and reviewing this document. You have pointed out significant issues surrounding the reuse of soil and have contributed significantly to the rewording of the language in this document regarding on-site and off-site berm reuse.

Responses to U.S. Army Environmental Center Comments

71. **Comment**

The entire document should be revised to emphasize that it is only discussing closed ranges. Note that this is not the same as "closing" ranges. RCRA authorities are different for closed versus closing (i.e., still active) ranges. The entire document should be reviewed to delete "closing" range references and to appropriately insert references to "closed" ranges (or statements could later be read to apply to all ranges). For example, the first full paragraph on page 48 needs "on a closed range" inserted in both sentences or else the paragraph is inaccurate. Note that some of the statements pertaining to "closing" ranges are phrased as a "range that is being closed" and thus a search for the word "closing" will not catch them all.

Response

The title now includes the term "closed" and the paragraph you referenced has been changed as requested. The phrase "a range being closed" occurs in Section 5.0 and the Executive Summary. These references remain since they apply to closing as well as closed ranges.

72. **Comment**

The title of the document needs to include the fact that it relates to closed ranges.

Response

The change has been made.

73. **Comment**

Several portions of the document are confusing when discussing the RCRA status of soil. For example, soil does not have to be removed (i.e., dug up) just because it fails TCLP. Cleanup authorities require an unacceptable risk to human health or environment based on the future land use. Additionally, soil is not a RCRA waste. See for example *Chemical Waste Management v. EPA*, 869 F.2d 1526 (D.C. 1989). The contained-in policy, therefore, needs to be explained.

Response

See responses to the more specific comments below.

74. **Comment**

Executive Summary, 5th paragraph. Delete the first two sentences. (These sentences refer to best management practices, etc. that we may not agree with. Moreover, we may not agree with the statement that they allegedly will "prevent regulatory problems." More fundamentally, though, these types of BMPs would apply, if at all, to active ranges, not the subject of this document.)

Response

The sentences you suggest be deleted do not allege (i.e., declare) that regulatory problems will be prevented. The statements are a positive reinforcement to steps that have been taken and continue to be taken to improve practices that have raised concerns. The sentences remain for that very reason.

75. **Comment**

Executive Summary, 7th paragraph, second bullet. Add at the end of the 2nd sentence, "… if the soil is to be taken off site and the soil fails a RCRA characteristic."

Response

The reference to RCRA is made in paragraphs immediately preceding the referenced paragraph, so the reader is quite certain of the regulatory environment we are speaking about. There seems to be little value providing this level of clarity in an executive summary.

76. **Comment**

Executive Summary, 7th paragraph, 2nd bullet, last sentence. Delete "regulators" and insert "regulations and regulatory agencies."

Response

Thank you for that clarification. The change has been made.

77. **Comment**

Section 4.0. The references to "range operators" should be deleted as irrelevant to this document. Replace it with "owners/operators of closed ranges."

Response

The changes have been made as requested.

78. **Comment**

Section 4.1, 1st paragraph. Delete the last sentence.

Response

The team agreed that these are the appropriate regulatory avenues to evaluate the environmental performance at operating ranges if the site is not listed on the National Priorities List under Superfund. We will insert the words, "If the site is not listed on the National Priorities List under Superfund…" to the beginning of the sentence.

79. **Comment**

Section 4.1, 2nd paragraph. Rephrase the third sentence to read, "Additionally, as outlined in the Federal Register (62 Federal Register 25998, May 12, 1997), processed scrap metal is exempted from RCRA regulation (i.e., is not a RCRA solid waste) when it is being recycled (40 CFR 261.3(a)(13).

Response

The phrase has been changed; however, you err slightly on the CFR citation. We have confirmed that 40 CFR 261.4(a)(13) is correct.

80. **Comment**

Section 4.2. Delete this section in its entirety as it doesn't pertain to "Federal Regulations and Guidance" for closed ranges. Instead, insert the following, "The management of wastes at closed military ranges may be shaped by USEPA's Military Munitions Rule (MMR). The final MMR did not address RCRA's application at closed ranges. USEPA may address this issue through future regulations."

Response
The section will be retained to inform the reader of the continually changing regulatory landscape for small arms firing ranges and the necessity to conduct the proper research and consult with the appropriate authorities for the most recent relevant regulations regarding range remediation. It lets the reader know that lead bullets are not considered hazardous waste upon deposition and, therefore, firing ranges are not hazardous waste landfills until the range has been "abandoned" (closed greater than 90 days). This understanding leads to greater flexibility while handling soils during remediation.

81. **Comment**
Section 4.3. The majority of this section deals with state laws and regulations that, if applicable at all, would be for an active range—again, this is irrelevant. This goes for the discussion of BMPs in the first part of the paragraph and bullets, the references to NPDES permitting in the second paragraph, and the discussion of permits for construction of new shooting ranges in the third paragraph.

Response:
We agree with your comment. However, we kept the section to make the reader aware of the wide degree of variation in regulations from state to state when it comes to managing lead-contaminated soils before, during, and after remediation.

82. **Comment**
Section 4.4 does not appear to discuss Remedial Objectives.

Response
The title of the section has been changed to Remediation/Future Use Issues.

83. **Comment**
Section 4.4, 2nd sentence. I recommend replacing "fail the TCLP test" with "are present in amounts that pose a risk based on the current or reasonably anticipated future land use" and replacing "violations" with "exceedances."

Response
These changes have been made.

84. **Comment**
Section 4.5, 1st paragraph, 1st sentence and 3rd paragraph, 1st sentence. Delete "firing range maintenance" as this phrase isn't relevant to closed/closing ranges.

Response
Comment accepted; the word "maintenance" will be removed.

85. **Comment**

Section 4.6, 1st & 2nd sentences. Rephrase as follows, "A potential hazard at Department of Defense small arms firing ranges are "live rounds," referred to as unexploded ordnance or UXO, from nearby or previously conducted large arms range activities. Additionally, all small arms ranges may contain live small arms rounds.

Response:

The changed paragraph now reads:

> **Live Rounds/UXO**
>
> A potential hazard at Department of Defense small arms ranges are "live rounds," referred to as unexploded ordnance or UXO, from nearby or previously conducted large arms range activities. Additionally, all small arms ranges may contain live small arms rounds. Quite often these items are overlooked in treatability testing or site characterization. Both are addressed in more detail below.

86. **Comment**

Section 4.6, 3rd paragraph. First sentence has a typo: change "he" to "the", and replace the second use of "UXO" with "large arms." Replace the rest of the paragraph with, "If physical evidence or historical records indicate the presence of UXO, an appropriate response should be conducted by an explosives or munitions response specialist prior to conducting any required intrusive activities at the closed range."

Response

Changes made to the first sentence as requested. With regard to the balance of the paragraph, the rest of the comment will be used to replace the second sentence.

The third and fourth sentences will remain unchanged, as the "hit" rate for UXO detection is typically expected to be 80% or better detection. With that in mind, it is imperative to have a second detection operation at the point of transfer to treatment operations, with the process operators trained in UXO detection in the unlikely event UXO turns up in the treatment plant.

The paragraph now reads:

> The intent of this section to emphasize that while the focus of this document is dealing with small arms firing ranges, experience has shown that unexpected UXO is occasionally present, even if there are no historic records indicating large arms use or storage at the site. If physical evidence or historical records indicate the presence of UXO, an appropriate response should be conducted by an explosives or munitions response specialist prior to conducting any required intrusive activities at the closed range. If UXO is present, a second sweep/clearance should be performed in the feed pile just prior to treatment. The process plant operators should also be trained in UXO recognition, with appropriate shutdown and notification procedures in place in the unlikely event UXO makes its way into the treatment plant.

87. **Comment**
Section 4.7, second to the last sentence. Please replace "permitted" with "allowed" to avoid confusion with the RCRA permitting process.

Response
Change completed.

88. **Comment**
Section 4.8, last sentence. Delete "performed as part of range closure" to avoid confusion with the RCRA closure process.

Response
The change has been made as requested.

89. **Comment**
Section 4.9 needs to be rewritten to accurately describe the "contained-in" policy. See redline/strikeout on attached page below.

Response
The redline/strikeout version you provided will be included, except the references to "live rounds" will be retained. Also, the last sentence of your correction will be inserted, but the word "not" will be removed so that it reads as follows, "It should be noted that individual states may not utilize the contained-in policy (and thus these soils **would be** regulated under RCRA) or may have additional, more stringent disposal requirements."

90. **Comment**
Section 4.9, last sentence. I don't think that state regulations can be less stringent than federal.

Response
Comment accepted. "Less stringent" will be removed.

91. **Comment**
Section 5.0, 1st sentence. Change "contaminated with" to "contains." In the second sentence, delete "thus." Just because soil exceeds a RCRA characteristic does NOT mean it has to be dug up and treated or removed. Again, a response is needed only if there is an unacceptable risk to human health or the environment. Delete the last sentence because it discusses active ranges.

Response
Comment accepted; the requested changes will be made.

92. **Comment**
Section 6.2. Replace "fail the TCLP test" with "are present in amounts that pose a risk based on the current or reasonably anticipated future land use" and replace "violations" with "exceedances."

Response
The change has been made as requested.

APPENDIX I

ITRC Contacts, ITRC Fact Sheet, and ITRC Product List

Small Arms Firing Range Team Contacts

Mark Begley
Bureau of Waste Site Cleanup
One Winter Street
Boston, MA 02108
P: 617-556-1071
F: 617-292-5530
mark.begley@state.ma.us

Gary Beyer
TNEC
P.O. Box 13087
Austin, TX 78711-3087
P: 512-239-2361
F: 512-239-2346
gbeyer@tnrcc.state.tx.us

Michael Burkett, Vice President
Metals Treatment Technologies
12441 West 49th Ave, Suite #3
Wheat Ridge, Co 80126
P: 303-456-6977
F: 303-456-6998
mburkett@metalstt.com

Marshall Bracken Jr.
Surbec-ART Environmental
3200 Marshall Ave, Suite 200
Norman, OK 73072
P: 405-364-9726
F: 405-366-1798
jrinokia@aol.com

John Buck
US Army Environmental Center
Building 4430
Aberdeen Proving Ground, MD 21010
P: 410-436-6869
F: 410-436-6836
John.buck@aec.apgea.army.mil

Greg Butler
BEM Systems
1600 Genesee, Suite 610
Kansas City, MO 64102
P: 816-842-7440
F: 816-842-7844
gbutler@bemsys.com

Robert Byrne, Wildlife Prog. Coordinator
Wildlife Management Institute
1101 14th Street, N.W. Suite 801
Washington, D.C. 20005
P: 202-371-1808
F: 202-408-5059
wmibb@aol.com

Elizabeth Callahan
MA Dept of Environmental Protection
1 Winter Street
Boston, MA 02108
P: 978-661-7722
F: 617-292-5850
elizabeth.j.callahan@state.ma.us

William Call
PMK Group
P: 732-751-0799
bcall@pmkgroup.com

John L. Cefaloni
RangeSafe Technology Demonstration
Initiative (RTDI)
US Army AMSTA-AR-WEA
Building 321
Picatinny Arsenal, NJ
P: 973-724-3295
F: 973-724-3162
C: 973-220-8192
John.cefaloni@us.army.mil

James F. Crowley, P.E.
RMT, Inc.
744 Heartland Trail
Madison, WI 53717
P: 608-662-5322
F: 608-831-3334
jim.crowley@rmtinc.com

Jim Dawson, Principal
Concurrent Technologies Corporation
999 18th St., Suite 1615
Denver, Co 80202
P: 303-297-0180
F: 303-297-0188
dawson@ctc.com

Scott Edwards
Senior Program Manager
Metals Treatment Technologies
7928 Bayberry Drive
Alexandria, VA 22306
P: 703-765-3510
F: 703-660-9296
sedwards@metalstt.com

Stacey L. French, Environmental Engineer
SC Dept of Health & Envir.
2600 Bull Street
Columbia, SC 29201
P: 803-896-4255
F: 803-896-4002
frenchsl@columb34.dhec.state.sc.us

Stephen C. Geiger
The RETEC Group, Inc./ESTCP
2111 Wilson Blvd., Suite 700
Arlington, Va 22201
P: 703-351-5086
F: 703-351-9292
sgeiger@retec.com

Dib Goswami, Co-Team Leader
Washington Dept of Ecology
1315 4th Avenue
Kennewick, WA 99337
P: 509-736-3015
F: 509-736-3030
dgos461@ecy.wa.gov

Ed Guster
USEPA
290 Broadway 22nd Floor
DECA-RCB
New York, NY 10007
P: 212-637-4144
F: 212-637-4949
Guster.Edward@epa.gov

Charles Harman
AMEC Earth and Environmental, Inc.
205 Division Ave., Suite 100
Somerset, NJ 08873
P: 732-302-9500
F: 732-302-9504
charles.Harman@amec.com

John Harris
Cal/EPA-DTSC
8800 Cal Center Drive
Sacramento, Ca 95826
P: 916-255-3883
F: 916-255-3734
jharris3@dtsc.ca.gov

Steve R. Hill
Reg-Tech, Inc.
2026 North Meyers Drive
Pine, Idaho 83647
P: 208-653-2512
C: 208-250-4392
F: 208-653-2511
srhill1@mindspring.com

Keith Hoddinott, Senior Soil Scientist
US Army Corps of Engineers
3743 Ady Road
Street, MD 21154
P: 410-436-5209
F: 410-436-8170
Keith.hoddinott@apg.amedd.army.mil

Terry Jennings
Concurrent Technologies Corporation
999 18th St, Suite 1615
Denver, Co 80202
P: 303-297-0180
F: 303-297-0188
jenningt@ctc.com

Satish Kastury
Florida Department of Environmental Protection
Twin Towers Office, 2600 Blairstone Rd
Tallahassee, FL 32399
P: 850-921-9232
F: 850-921-8018
Satish.kastury@dep.state.fl.us

Jeff Lockwood
FL Dept of Environmental Protection
2600 Blairstone Road, Room 438J
MS 4535
Tallahassee, FL 32301
P: 850-488-3935
F: 850-922-4939
jeff.lockwood@dep.state.fl.us

James Marsh
RIO Technical Services
4200 South Hulen, Suite 630
Fort Worth, TX 76109
P: 817-735-8264
F: 817-735-8342
Jim.marsh@riotechnical.com

George Meyer
USEPA
290 Broadway 22nd Floor
DECA-RCB
New York, NY 10007
P: 212-637-4144
F: 212-637-4949
meyer.george@epa.gov

June Mirecki
US Army Corps of Engineers
P: 601-634-4003
june.e.mirecki@erdc.usace.army.mil

Robert T. Mueller, Co-Team Leader
New Jersey DEP
401 E. State Street
P.O. Box 409
Trenton, NJ 98625
P: 609-984-3910
F: 609-292-7340
bmueller@dep.state.nj.us

R. Richard Patterson, Director
National Shooting Sport Foundation
11 Mile Hill Road
Newtown, CT 06470-2359
P: 203-426-1320
F: 203-426-1087
rpatterson@nssf.org

Ed Stevenson
New Jersey Department of Environmental Protection
401 East State Street
PO Box 409
Trenton, NJ 08625
P: 609-633-1342
F: 609-292-7340
estevenson@dep.state.nj.us

Peter M. Strauss
PM Strauss & Associates
317 Rutledge Street
San Francisco, CA 94110
P: 415-647-4404
F: 415-647-4404
petestrauss1@attbi.com

Mike Warminsky, Technical Director of Remediation
AMEC Earth & Environmental, Inc.
285 Davidson Avenue, Suite 100
Somerset, New Jersey 08873
P: 732-302-9500
F: 732-302-9504
mike.warminsky@amec.com

Kimberly Watts
USAEC
SFIM-AEC-PCT
5179 Hoadley Rd
Aberdeen Proving Ground, MD 21010
P: 410-436-8843
F: 410-436-6843
Kimberly.watts@aec.apgea/army.mil

Rafael Vasquez, Environmental Engineer
Air Force Center for Environmental Excellence
HQ AFCEE/ERT
3207 North Road
Brooks AFB, TX 78235-5363
P: 210-536-1431
F: 210-536 4330
Rafael.vasquez@hgafcee.brooks.af.mil