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ARMY SMALL ARMS TRAINING RANGE ENVIRONMENTAL BEST MANAGEMENT PRACTICES (BMPs) MANUAL

Prepared for:
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Gene Fabian, U.S. Army Aberdeen Test Center
Kimberly Watts, U.S. Army Environmental Center

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14. ABSTRACT
The BMP manual serves as guidance for the greater range community on how to address or mitigate any identified areas of concern on small arms ranges. Guidance is provided to support the selection and implementation of management methods for erosion or lead migration issues based on site specific use and environmental characteristics. The range area evaluation procedures, range operation and management strategies and range modification guidance discussed in the BMP Manual are designed to be low cost and feasible approaches for any installation to use to improve the environmental quality and insure the long-term sustainability of essential training areas. Guidance documents generated from this program will also be incorporated into standard range design manuals issued by the U.S. Army Corps of Engineers.

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Author:

Gene Fabian
Military Environmental Technology Demonstration Center (METDC)
U.S. Army Aberdeen Test Center (ATC)
U.S. Army Aberdeen Proving Ground (APG)

Contributor:

U.S. Army Environmental Center (USAEC)
U.S. Army Aberdeen Proving Ground

Executive Summary

The U.S. Army Aberdeen Test Center's (ATC's) Military Environmental Technology Demonstration Center (METDC) has developed this operational Army Small Arms Training Range Environmental Best Management Practices (BMPs) Manual for the U.S. Army Environmental Center (USAEC) under the Advanced Range Design Program, U.S. Army Developmental Test Command (DTC) Project No. 9-CO-160-000-504, a part of USAEC's Sustainable Range Technology Program. This manual is intended to be a reference guide for installation and range personnel for use in maintaining the long-term sustainability of their operational small arms ranges and range areas. This document aims to illustrate the ability to proactively improve both the environmental conditions of a range and the range's mission of troop training and readiness. The main environmental concern this document addresses is the transport of small arms metal munitions constituents, primarily lead, from operational small arms range areas. Proactive, environmentally-sound management of range areas may allay State and Federal environmental regulatory agency concerns with the use of small arms munitions and control of their metal constituents.

This manual is for use by U.S. Army installations for identifying, via an internal evaluation of small arms ranges, the potential for metal munitions constituents transport and erosion concerns associated with routine training activities at operational small arms firing ranges. In addition, this manual serves as guidance on how to address or mitigate any identified areas of concern that can be addressed through relatively simple changes in the way the range is operated and maintained, or by performing range modifications.

The small arms range area evaluation procedures, range operation and management strategies, and ways to modify ranges discussed in this manual are designed to be low-cost and easily feasible approaches for any installation to use to improve the environmental quality and ensure the long-term sustainability of essential training areas.

This BMPs manual is not intended to serve as guidance for a thorough environmental investigation, site characterization, or risk assessment of small arms ranges. An environmental investigation or characterization can be a recommendation produced by the range evaluation process, but a formal environmental site characterization or human health and ecological risk assessment is beyond the scope of this BMPs manual. Information sources are found throughout the manual. This manual is divided into sections that include:

- operational small arms range evaluation procedures.
- range improvement methods (BMPs).
- monitoring effectiveness of range improvements.
- economic analysis.
- potential funding sources for range modifications and maintenance.

This manual does not provide guidance or advice regarding the potential applicability of any environmental laws or regulations to small arms ranges. Such determinations must be made in consultation with your installation's environmental personnel and attorney. This manual does not provide guidance or advice regarding whether environmental laws or regulations are applicable to the implementation of any of the BMPs. The evaluation of any site-specific BMPs should include consultation with the installation environmental and legal staff to ensure that any legal or regulatory requirements are considered during BMP evaluation and are implemented if the BMP is chosen.

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Army Small Arms Training Range Environmental Best Management Practices (BMPs) Manual

1. Introduction

Small arms ranges are essential to weapons training and the mission of the U.S. Army. Operational small arms range use produces soil laden with metals from the spent rounds. These metal constituents have the potential to create environmental problems during range operation and maintenance. The primary concern addressed by this manual is metal constituent migration from operational small arms ranges. Proper management of operational small arms ranges can alleviate these problems.

Bullets are often fragmented and pulverized upon impact with the ground, backstops, berms, or bullet traps located on operational small arms ranges. Antimony, copper, lead, and zinc contribute to small arms munitions constituent soil loading. In this manual, lead is the primary munitions constituent of concern with respect to its potential to transport off of the small arms ranges. As with most metals, lead, antimony, copper, and zinc generally tend to adhere to soil grains and organic material and remain fixed in shallow soils. This manual's focus on lead as the primary constituent of transport concern is based on the relative mobility of the small arms metals, the concentrations of the metals found in the soil on the range, and the relative toxicity of the metals based on regionally published U.S. Environmental Protection Agency (USEPA) risk-based concentrations for soil and water.

From the standpoint of mobility, lead and copper have the lowest potential for mobility (ref 1). These metals and their metal salts commonly found on small arms ranges generally have relatively low solubility constants in soil. Antimony generally has moderate mobility in soil and remains readily adsorbed to soil particles in neutral to low pH ranges (ref 1). Zinc is highly mobile in soil (ref 1) and has the potential to migrate off range. Lead and copper are found in the highest concentrations on the range. The normal operation of a range can produce lead concentrations of several percent in soils located behind and adjacent to targets and impact berms. Zinc concentrations are generally one to two orders of magnitude lower (hundreds to high thousands of mg/kg) and antimony is generally found in concentrations of tens to low hundreds of mg/kg of soil. Using risk-based concentrations as a guide, copper and zinc have a relatively low toxicity. Lead and antimony toxicities are relatively high. Based on this information, copper and zinc, though found in significant concentrations in the soil on the range, generally pose a relatively low risk to migration, exposure in transport pathways off range, or both. Antimony, though having a moderate potential for migration and a high toxicity, is generally found in low concentrations on the range and does not appear to have produced a significant exposure risk in transport pathways off range. Lead, though having low mobility characteristics in soil, is found in far greater concentrations on the range and has a higher potential to be detected in transport pathways off range. Coupled with its relatively high toxicity, lead is believed to be the munitions metal constituent of primary concern with respect to potential off range transport and potential exposure in transport pathways. Care must be taken to protect human health and the environment from the potential harmful effects of lead (ref 2). Additionally, lead transport is easier to identify due to the relatively higher lead concentrations that may migrate off range. As a result lead migration can serve as tracer or indicator of other metal constituent transport that may occur at much lower concentrations. The range evaluation procedures and BMPs identified in this manual focus on the mitigation of lead migration. These BMPs generally will also address any migration issues that may exist with respect to the other small arms metal munitions constituents.

1.1 BMPs Manual Purpose

This manual is intended to be a reference guide for installation and range personnel for use in maintaining the long-term sustainability of their operational small-arms ranges and range areas. The manual aims to illustrate the ability to improve both the environmental conditions of a range and the range's mission of troop training and readiness. The main environmental concern this document addresses is the transport of metal small arms munitions constituents, primarily lead, from operational small arms range areas. Proactive, environmentally-sound management of range areas may allay State and Federal environmental regulatory agency concerns with the use of small arms munitions and control of their metal constituents.

The range area evaluation procedures, range operation and management strategies, and ways to modify ranges discussed in this manual are designed to be low-cost and feasible approaches for any installation to improve the environmental quality and ensure the long-term sustainability of essential training areas.

1.2 Environmental Concerns

The basic environmental issues of concern at operational small arms ranges addressed by this manual are metal residues, soil erosion, and the active transport mechanisms such as surface water runoff or groundwater flow that may be moving these constituents off range areas. The fact that lead and other metal constituents are accumulating in the environment on the range as a result of operational small arms range use does not alone constitute a problem. Management or maintenance actions, if needed, should be based on the potential for the metals to transport out of the range area and their potential to reach receptors at levels that exceed established criteria. The evaluation process described in this manual focuses only on the potential to reach human receptors. The potential impacts to ecological receptors are currently being studied and are not addressed in this manual.

This BMPs manual is not intended to serve as guidance for a thorough environmental investigation, site characterization, or risk assessment of small arms ranges. The objective of the range evaluation portion of this manual is to perform a subjective evaluation of munitions metal constituent transport with the option of limited field sampling to determine what potential environmental concerns may exist at a small arms range as a result of training operations, site-specific conditions, range design features, and maintenance procedures. It is not intended to serve as a formal site characterization or risk assessment where a systematic sampling of all environmental media would take place, sampling to establish background concentrations of pollutants would be performed, etc. Common problems such as soil erosion and sediment/storm water runoff, as well as the issue of lead residue and its potential migration in the environment, are the focus of the evaluation. The execution of this evaluation should be coordinated with the installation's environmental management. An environmental investigation or characterization may be a recommendation produced by the range evaluation process, but a formal site characterization or risk assessment is beyond the scope of this BMPs manual. Information sources to support execution of the range evaluation process are found throughout the manual.

This manual does not provide guidance or advice regarding the potential applicability of any environmental laws or regulations to small arms ranges. Such determinations must be made in consultation with your installation environmental personnel and attorney. This manual does not provide guidance or advice regarding whether environmental laws or regulations are applicable to the implementation of any of the BMPs. The evaluation of any site-specific BMPs should include consultation with the installation environmental and legal staff to ensure that any legal or regulatory requirements are considered during BMP evaluation and are implemented if the BMP is chosen.

1.3 BMPs Manual Overview

This manual is organized to provide step-by-step guidance for range condition evaluation and BMP identification, if needed. The manual is designed to augment existing range assessment and maintenance identification guidance (ref 3) and support maintenance inclusion in facility Environmental Management Systems and Sustainable Range Management Plans (ref 4 and 5). The BMP descriptions provide the basic information to understand the BMP function, implementation requirements, and maintenance requirements necessary to select the most cost-effective means to control metals migration within range areas, budget for implementation and maintenance, and install and maintain the BMP within the overall range management plan. The manual is divided into sections that include

- operational small arms range evaluation procedures.
- range improvement methods (BMPs).
- assessing/monitoring effectiveness of range improvements.
- economic analysis.
- potential funding sources for range modifications and maintenance.

This manual is intended to provide range personnel a guide in determining cost-effective range environmental BMPs to mitigate small arms metals migration from the range area. The focus of this manual is solely on the U.S. Army small arms training ranges. BMP guidance for recreational ranges on U.S. Army property may be obtained from other sources such as the USEPA BMP guidance document (ref 6) or the Interstate Technology & Regulatory Council (ITRC) Environmental Management at Operating Outdoor Small Arms Firing Ranges document (ref 7). The focus of these documents is primarily outdoor recreational small arms range facilities.

This manual can be used in parts, but to gain the full benefit of applying need-focused BMPs under a range management plan, a sequence of erosion and lead mobility evaluation followed by BMP selection and implementation is recommended. The typical sequence of actions is shown in Figure 1-1. Each of these basic actions consists of a series of subordinate actions described in detail in this manual.

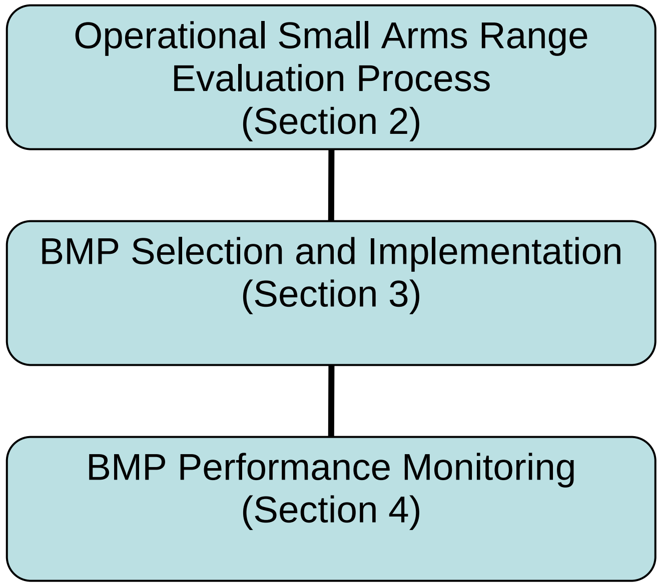


Figure 1-1. Recommended sequence of actions.

The operational small arms range evaluation involves the identification of potential soil erosion and metals transport resulting from small arms range use within each subwatershed in the range area. The sequence of investigative events is shown in Figure 1-2. Checklists of information needed to address the watershed delineation, background and range use, and range checks are presented in Tables 1-1 and 1-2. This information is used to run the Range Evaluation Software Tool (REST) program (para 2.2.3) and to develop a conceptual site model of the potential lead transport mechanisms within the range area. The potential for human exposure to lead is also subjectively evaluated and identified in the conceptual site model. The development of this model is discussed in paragraph 2.2.5.

After the initial identification of potential lead transport issues, an optional field data collection effort may be conducted at the installation's discretion. The objectives of the follow-up data collection effort may be to

- support the results of the evaluation, or
- support implementation of BMP efforts, or
- establish a baseline for comparison to and evaluation of BMP performance, or

- determine whether environmental investigations (e.g., Preliminary Assessment) should be performed if the evaluation identified the potential for metals transport out of the range areas or the potential for human exposure exists.

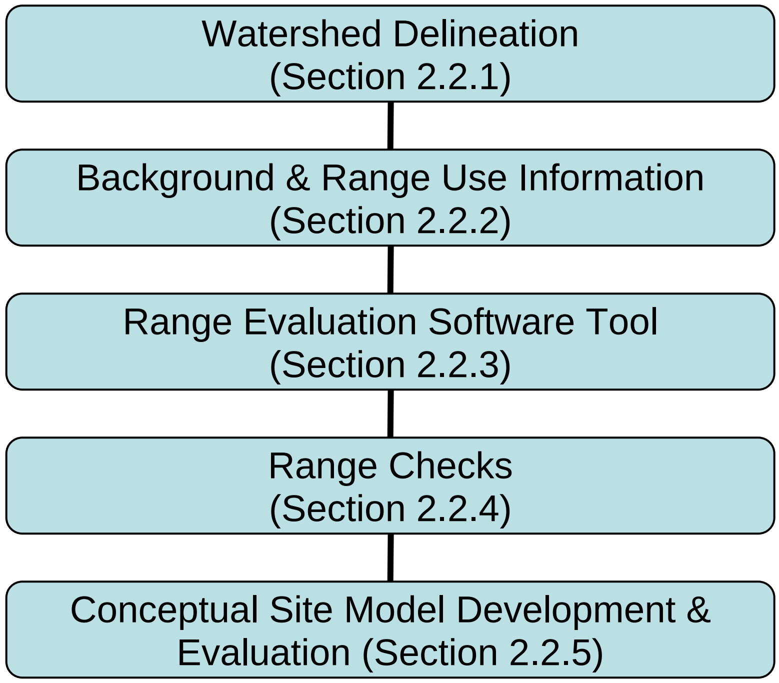


Figure 1-2. Range evaluation process.

Data collection results are not intended to support environmental site characterization or risk assessment efforts. Data collection efforts will focus on the range areas, transport pathways, and media identified by the conceptual site model as being potentially impacted by lead transport (see section 2.3). If the results of the conceptual site model or data suggest that lead transport or exposure concerns exist, then two actions should be taken simultaneously. First, the installation's environmental office should be informed to determine if the data results trigger any regulatory notification requirements and to request that the environmental office conduct appropriate investigations of off-range metals concentrations. Second, appropriate sustainment methods should be selected and implemented to mitigate continued metals transport or soil erosion from the range areas.

If, based on either the conceptual site model alone or on both the conceptual site model and data collection results, no potential metals transport or human exposure is indicated then no further investigative actions need to be performed, nor do BMPs need to be implemented based on current range use and condition. Data collected may be used at the option of the range personnel to identify improved range and training area maintenance practices that may ensure sustained range availability.

TABLE 1-1. WATERSHED AND BACKGROUND INFORMATION CHECKLIST

Required Information		Manual Paragraph
Contour maps	Watershed delineation maps.	2.2.1
	Range area overlay.	
Soil	Soil classifications.	2.2.2
	Soil texture.	
	Erosion factors.	
	Permeability.	
	Available water capacity.	
	Soil texture of berm (if used on range).	
	Mineralogy and subsurface stratification.	
Groundwater	Depth to groundwater.	
	Aquifer characteristics beneath range (thickness, size, or aerial extent).	
	Aquifer productivity and regulatory classification.	
	Direction of groundwater movement.	
	Location of potable water wells within 1/2 mile of range(s).	
	Potable water use information.	
	Surface seeps or discharge points (such as streams).	
Surface Water	Surface water use information (regulatory classification).	
	Distance from range area to water resource.	
	Slope of the land between water resource and range.	
	Vegetation between water resource and range.	
	Storm water drainage systems that create a direct pathway from range to water resource (such as drainage pies).	
	Other structures or activities that may impact water resource.	
Climate	Rainfall data (2-year, 24-hour depth, and monthly average depth. Estimated transport distribution of annual precipitation via evaporation/transpiration, runoff, and groundwater recharge).	
	Wind data (direction, monthly average speed, peak gust speed).	
	Temperature (monthly average, high, and low).	
Geographical	Distance to installation boundary.	
	Distance to cantonment area.	
	Distance to other sensitive habits or areas of potential human exposure.	
Range type(s) and use	Range type.	
	Length of time range(s) has been in use.	
	Historical and current munitions types used on the range(s).	
	Historical and current munitions quantities used on the range(s).	
	Typical distribution of shooters across range firing lanes.	
	Current range maintenance procedures.	

TABLE 1-2. RANGE CHECK CHECKLIST

Required Information	Range Observations
Predominant small arms round impact locations	Location(s) with respect to individual ranges.
	Location(s) within subwatershed.
	Direct impact into surface water resources (stream, lake, wetland, etc.).
Predominant small arms round condition at each impact location	Physical condition (intact, large fragments, dust sized fragmentation).
	Corrosion condition (presence of corrosion production on round or surrounding soil, color, easily removed or tightly adhering corrosion).
Land/erosion characteristics at each impact location	Soil texture.
	Slope (include berm dimensions if berm is used).
	Soil pH.
	Surround vegetative cover (type, density, vigor).
	Erosion evidence (small arms round and rainfall impact erosion, rills, gulleys, sediment deposition in surrounding area).
	Storm water flow path delineation.
Surface water proximity to each impact location	Distance to surface water source.
	Surface water physical characteristics and stream health (if applicable).
	Natural conditions between each impact location and surface water resource (erosion evidence, vegetation, riparian zones, bank stability, etc.).
	Man-made structures between each impact location and surface water resource that may affect storm water flow paths or erosion characteristics.
	Estimated groundwater proximity at each impact location; evidence of groundwater seeps between impact locations and surface water resources.

The main purpose of BMPs is to sustain range availability for training use. The results of the range evaluation will drive the need for BMP implementation. As stated above, if no potential metals transport or exposure issues are indicated by the evaluation, then BMP implementation will not be required. However, if the evaluation indicates that one or both of these potential issues exist, then the implementation of environmental sustainment (BMP) methods should be limited to the minimum required to address the operation, site-specific condition, range design feature, or maintenance procedure that most affects lead transport. The range sustainment methods may involve the prevention of metals migration, pollution prevention, or metals removal methods. These methods may be applied in a complimentary or cumulative way to achieve desired mitigation results. Following are BMP method categories that may be used to resolve potential range use issues.

Prevention of Metals Migration

- operational changes
- vegetative solutions
- storm water management
- berm design and structural enhancements
- geosynthetic materials
- soil amendments

Pollution Prevention

- green ammunition
- bullet traps

Metals Removal

Each of these BMP method categories is discussed in detail in section 3, and each BMP includes the following information:

- description
- benefit
- applicability
- limitations
- implementation guidance
- maintenance requirements
- cost elements

Selection of the appropriate BMP(s) for a small arms range training area should be based on the data collected during the range evaluation. A four-step process has been developed that progressively screens the BMPs identified in section 3 based on range-type suitability, metals transport mechanism suitability, physical site characteristic suitability, and a final trade-off analysis (ref 8). This process is described in section 3.1.

The remainder of this manual provides guidance to monitor the effectiveness of the BMPs implemented in the range area (section 4), develop budgeting cost estimates for implementation and maintenance of BMPs (section 5), and find potential funding sources for range BMP and modification projects (section 6).

2. Operational Small Arms Range Evaluation Process

2.1 Evaluation Objective

The basic environmental issues of concern at operational small arms ranges are metal residues, soil erosion, and the active transport mechanisms, such as surface water runoff or groundwater flow that may be moving these constituents off range areas. The fact that metals are accumulating in the environment as a result of operational small arms range use does not alone constitute a problem. BMP implementation, if appropriate, should be based on an evaluation of potential transport of the lead being placed on the operational small arms range.

The operational small arms range evaluation consists of the following actions:

- A site-specific evaluation that identifies the potential for munitions constituent movement.

- A subjective evaluation of human exposure in transport pathways.

The objective of the evaluation is to determine what metals transport concerns exist at a small arms range as a result of training operations, site-specific conditions, range design features, and maintenance procedures. This evaluation is not intended to serve as a site characterization where a systematic sampling of all environmental media would take place, sampling to establish background concentrations of pollutants would be performed, etc. Common problems such as soil erosion and sediment/storm water runoff and the potential migration of metals residue are the focus of the evaluation.

An individual firing range and its surrounding areas should be examined as a whole to identify their potential effects on one another and the contribution(s) each makes to metals transport. Typically, an entire series or complex of ranges is near one another. The scale of an operational small arms range evaluation must consider the combined or cumulative effects of the entire range complex on the watershed(s) in which it lies. As such, the initial unit for evaluation is on the watershed or subwatershed scale.

Performing the evaluation on this scale is based on the assumption that the most likely environmental concerns from range areas will be the impact from soil erosion and metals residue transport in storm water runoff and potential leaching of metals into groundwater. By defining watershed boundaries, the operational small arms range(s) that may be impacting a specific watershed (and its ground or surface waters) can then be identified, grouped, and further assessed. If subsequent field surveys/checks or sampling determines there are environmental concerns within the watershed, it will be easier to determine what area(s) might be the source for those concerns and what BMPs may be implemented to address or mitigate those concerns.

In cases where the ranges and impact areas are located on land that has no surface water resources or overland storm water flow, the evaluation approach may deviate from the watershed approach. In these cases, infiltration or aerial transport may be the primary transport

Why use a Watershed Approach?

The watershed approach to range evaluation and management outlined in this manual has been developed and is recommended for several reasons. First, the watershed management perspective is consistent with current and future nonpoint source water quality guidance. In addition, a watershed represents a defined area and true boundary from a functional environmental perspective. In general, surface waters, storm water runoff, and shallow groundwater movement are grouped or confined to a well-defined watershed or subwatershed. Within the watershed, most influences or potential pollution sources can be identified and their contributions to any pollution gauged to whatever degree desired; they can then be accounted for and managed. In contrast, firing range boundaries are arbitrary lines on a map that have no meaning from the functional environmental perspective.

Evaluating a range or range complex on the watershed scale will help focus the limited resources available. Areas that need the most help can be identified and prioritized. Locations can be identified to maximize benefits by performing any modifications or management efforts in strategic locations where they can address the greatest number of problems.

Surface water resources represent the pathway where range pollutants can be quickly transported. These resources also have water quality standards that can be contrasted against sampling results to help evaluate the potential impact of range activities on these water resources.

mechanisms. In order to account for this, watershed delineation would not be necessary. The evaluation approach would continue to concentrate on the range areas where the rounds predominantly impact. This manual's evaluation process will focus on the watershed delineation approach, but if surface transport via storm water does not apply then the reader should modify the evaluation guidance to delineate areas of predominant metals buildup.

An evaluation of a small arms range training area is recommended to be accomplished in three steps. The steps of the evaluation and a partial listing of the types of information collected and data generated for each step are listed below.

Step I - Range Evaluation

- watershed delineation for range areas/complex
- background and range information collection
- REST analysis of ranges (optional)
- range checks
- conceptual site model development

Step II - Additional Data Collection (optional)

- sampling based on conceptual site model
- refinement of conceptual site model with field data

Step III - BMP Implementation Requirements

- determination of whether BMP efforts are needed
- consult with environmental management to determine whether additional actions are needed to investigate potential metals transport or exposure.

The execution of this evaluation should be coordinated with the installation's environmental management. The range evaluation aims to answer questions such as the following:

- Is soil erosion and sediment runoff occurring?
- Is there a potential human exposure or transport concern with metal munitions constituents?
- What transport mechanism(s) or site-specific factors are responsible for transport concerns (e.g., particles of lead transported in eroded soils and storm water runoff, wind transport of lead contaminated soil particles)?
- Where might range generated munitions constituents go?
- What off-range areas (such as nearby streams, ponds, or wetlands) are potentially affected by sediment runoff or metals migration/accumulation?

Evaluating a range for metals transport concerns is not likely a one-time effort. Range evaluation is recommended on a regular basis, such as once every 5 years (or more frequently), to monitor the range, particularly if range conditions or range use significantly changes after an evaluation has been completed.

2.2 Step I - Range Evaluation

The evaluation is an effort to obtain general background information and to identify areas where metals transport might exist. Much of the needed information can be gained through general information gathering, range checks, and review and analysis of factors such as current range operating and maintenance procedures. Data collection for this step can be performed by range personnel or installation environmental personnel with no environmental sampling required. This information may be used in later portions of the overall range evaluation to aid in drafting field sampling plans and provide information needed for the design of BMPs such as storm water management systems. Checklists for gathering data and performing range checks are provided in Appendix A. The end product of the data collection effort will be the development of a conceptual site model as described in section 2.2.5. This model is a summarization and interpretation of the data collected that describes the current condition of the ranges and surrounding areas as well as the potential transport of metal constituents. Potential human exposure issues are also identified. This model is then used to determine whether BMPs are necessary to control metals transport.

2.2.1 Watershed Delineation

Proper watershed delineation is crucial to determining the potential surface water flow across a range area (fig. 2-1). Once the watershed(s) and subwatersheds have been identified, a range check can further define where the water is going and help evaluate the effect the water is having on erosion and metals transport.

How to Delineate a Watershed

The USEPA has a Web-based tool that will show the large-scale watershed for the region by typing the area's zip code (http://cfpub.epa.gov/surf/locate/index.cfm). Another USEPA Web based tool offers interactive maps that will zoom-in on the watershe (http://map2.epa.gov/enviromapper). In addition, many State environmental agencies have detailed watershed delineation maps available on-line. On-line watershed delineation training modules c be found on the USEPA's Watershed Academy Web site (http://www.epa.gov/owow/watershed/wacademy).

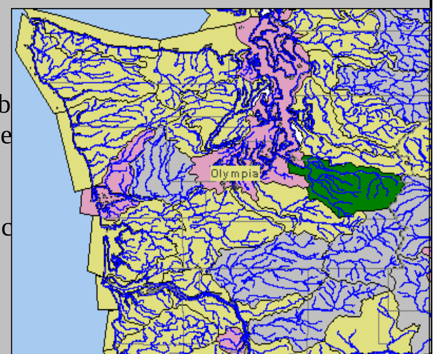


Figure 2-1. USEPA's Enviromapper Web tool.

Detailed contour maps of the land surface also allow for the delineation of watershed boundaries. The range may have been surveyed when it was constructed or renovated at some point in time. The survey and construction/design drawings produced by such efforts may provide elevation contour maps for surface topography. These maps may contain enough information to delineate the watershed boundaries and should contain information such as the dimensions and land area of the range. An installation's Department of Public Works (DPW), facilities, or real estate office are potential sources for maps and engineering drawings that can provide physical data on the range. Many installations have Geographic Information Systems (GIS) that are able to generate maps with information that delineates watersheds and surface topography, calculates land areas, etc. The United States Geologic Survey (USGS) is also a source for detailed topographic maps for almost all locations within the United States.

FOR MORE INFORMATION

For more information on the mapping information and services offered by USGS, visit the USGS Website: http://mapping.usgs.gov/www/products/1product.html

Surface elevation contour maps can be used to determine watershed boundaries by evaluating the patterns in land surface height changes. Detailed topographic maps of relatively small areas typically have contour intervals of 2 feet (although the contour interval can be any increment), meaning each line represents a 2-foot change in the height of the land surface. Flow paths of surface water runoff can be determined by drawing flow lines perpendicular to the surface height contour lines from higher elevation to lower elevation. Using this method, the boundaries for the watershed within which the range lies can be determined. An example of drawing surface water flow lines from surface height contour lines is shown in Figure 2-2. Watershed boundaries and area information can then be used to aid in planning range evaluation efforts, targeting areas for future sampling, calculating surface water runoff volumes and patterns, and designing storm water management systems (if needed).

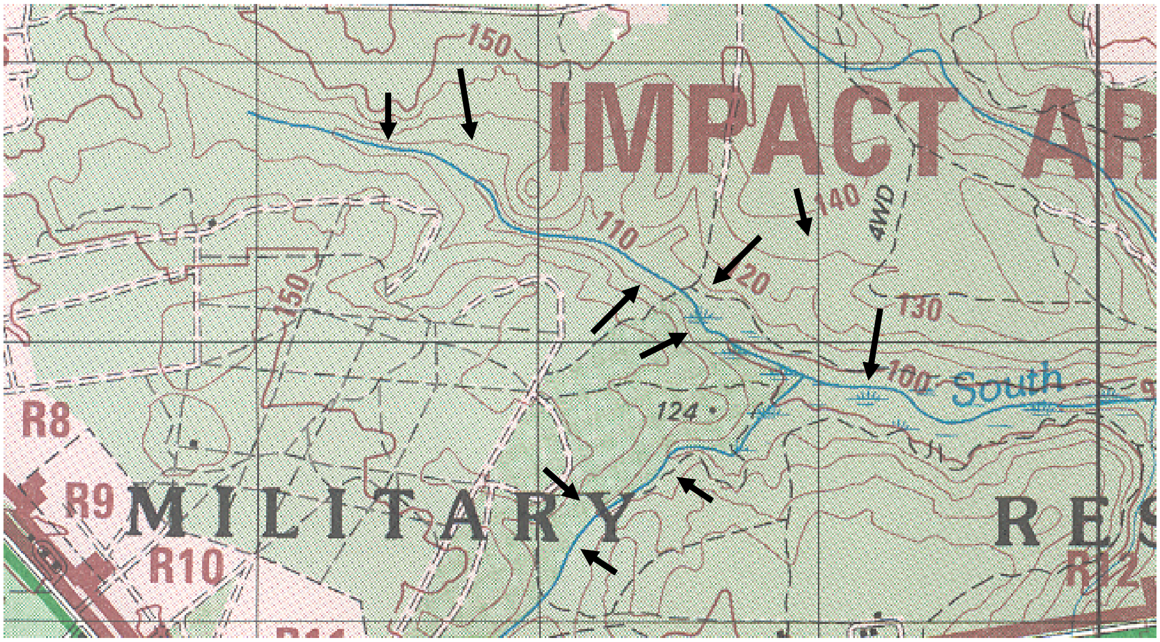


Figure 2-2. Surface water flow lines drawn across elevation contour lines.

2.2.2 Range Background and Range Information Collection

Range background and range use information is necessary to conduct an evaluation. Categories usually available to support the evaluation include

- geographical information.
- soil type(s), geology, and subsurface stratigraphy information.
- groundwater information.
- surface water resource information.
- climate and precipitation information.
- range use information.

The type of information for each category necessary to develop a conceptual site model of the range areas and potential sources of the information are presented below.

Geographical Information

The distance from the range or range complex to the installation boundary or cantonment areas should be determined. In addition, any transport pathways such as streams or groundwater flow that could potentially carry munitions constituents across this distance should be identified. The evaluation subjectively identifies whether or not this potential transport exists and what may be mitigating or supporting that transport. Sources for geographical information include the installation GIS, DPW, and environmental offices.

Soil Types, Geology, and Subsurface Stratigraphy

Soil types for the areas on the range where rounds impact can provide some insight to the potential fate of the metal in the environment. For example, the erodability or erosion factor of the soil varies with the physical characteristics of the soil type. Soils with high infiltration rates generally have a greater resistance to erosion. Examples of soils with this characteristic include sand, sandy loam, and loam textured soil. Soils with low infiltration rates have small soil particles that may easily compact and result in increased runoff during storm events. These soils are more likely to erode because of this runoff and the tendency of the small soil particles to easily suspend and be transported in the runoff water. Examples of soil with these characteristics are silt, very fine sand, and clay textured soils. Soils that are easily eroded may result in a high concentration of lead associated with the suspended solids in the runoff water.

Soil type can also affect the corrosion rate of the metals in the environment, thus resulting in higher concentrations of dissolved-phase metal ions or metal adsorbed to soil particles. Several factors or processes can affect the adsorption of metal ions to soil particles. These include the soil's cation exchange capacity (CEC), specific adsorption, co-precipitation, and organic complexation (ref 1). These factors and processes can vary widely in soils of apparently similar physical properties. Determining the predominant factor influencing adsorption to soil properties at a particular range is beyond the scope of this evaluation. To support the evaluation, the CEC of the soil is assumed to have a predominant influence on lead adsorption to soil particles. Generally, soil types with larger particle sizes and high infiltration rates will have lower CECs (sand) and will result in low lead adsorption to soil particles. Lead transport in this case may be predominantly through dissolved-phase movement in soil pore water or storm water runoff. Soils with smaller particle sizes will have higher CECs (silt and clays). These soil particles may have higher concentrations of adsorbed lead that may potentially be transported in storm water runoff. Further study is needed to develop field screening methods that will identify the other factors influencing lead corrosion and adsorption so that more accurate site-specific determinations of the effects of soil on lead transport can be made. The effects of soil type on the lead should be considered when investigating potential BMPs. BMPs may be ineffective if they do not address either the reactions occurring in the soil or the characteristic (solid or dissolved-phase) of the lead being transported.

Geology and subsurface stratigraphy can impact the surface or subsurface transport of the metals either physically or chemically. The physical stratification of soil layers can result in natural barriers to vertical and shallow subsurface horizontal transport of metals. The mineralogy of the soil may be such that naturally occurring salts (phosphate, sulfides, sulfates, carbonates, etc.) react with metal ions to form relatively stable precipitates that may effectively arrest transport from the range area. This natural stabilization can effectively mitigate any potential off-range transport from range use and should be considered in the evaluation of metal munitions constituent transport from the range.

Location information on the type(s) and classifications of surface soils at the range and nearby areas can usually be obtained from installation GIS maps. Additional information regarding the physical characteristics of soil types can be found in the soil survey reports published by the U.S. Department of Agriculture's (USDA's) Natural Resources Conservation Service (NRCS). Information contained in the survey includes maps delineating soil types; a general description of each soil type with a breakdown of percent components in particle size fractions such as sand, silt, and clay, and other mineral content; the productivity of a soil type (for vegetative purposes); and the erosion factor of a given soil type. Typically, there is a soil survey report for each county in every state in the United States. The NRCS maintains a World Wide Web page that provides soil survey report information and soil databases at http://www.nrcs.usda.gov/TechRes.html. In addition, an agricultural extension office of the USDA for most counties in the United States should be listed in the local telephone directory under government agencies. This office is an additional source for information on local soils.

FOR MORE INFORMATION

For more information on the soil survey reports and services offered by NRCS, visit the NRCS Website: http://www.nrcs.usda.gov/TechRes.html.

State geologic surveys or the USGS can provide information on local geology or stratigraphy. State Geologic Survey points of contact and information is on the Association of American State Geologists Web page at http://www.kgs.ku.edu/AASG/AASG.html. Geology and stratigraphy information may also be obtained from the installation's environmental office. Environmental investigations that involved the installation of wells either in the range areas or elsewhere on the installation may provide some insight into the general subsurface characteristics of the area. Although the data are not specific to the specific impact points on the ranges, they do provide a basis for an evaluation of the effects of subsurface characteristics on the transport of metal munitions constituent. A summary of the data requirements and potential sources is provided in Table 2-1.

TABLE 2-1. SUMMARY OF SOIL/GEOLOGY DATA REQUIREMENTS AND SOURCES

Soil Data	Data Sources
Soils classifications for all ranges and surrounding area	GIS and NRCS soil surveys
USDA soil texture	NRCS Soil Survey - Engineering Properties and Classifications Table
Erosion factors	NRCS Soil Survey - Woodland Management and Productivity Table
Permeability	NRCS Soil Survey - Physical and Chemical Properties of Soils Table
Available water capacity	NRCS Soil Survey Physical and Chemical Properties of Soil Table.
Soil texture of berm (if used on the range)	Berms may have been constructed from borrow pit soils. Consult construction drawings for soil type used in construction of the berm.
Mineralogy and subsurface stratification	Installation environmental office well drilling logs or USGS.

GIS = Geographic Information Systems.
NRCS = Natural Resources Conservation Service.
USDA = U.S. Department of Agriculture.
USGS = United States Geologic Survey.

Groundwater Information

Generally, shallow groundwater (less than 10 feet below ground surface) is susceptible to being impacted by lead if the overlying soil is highly permeable. This shallow water, if partially or totally isolated from underlying aquifers may also discharge as base flow via seeps to nearby surface water bodies. If conditions such as these are found to exist in close proximity to lead source areas, consideration should be given to conducting a more detailed assessment, to include sampling of groundwater and surface water.

Where only highly permeable soil is between the ground surface and an aquifer used for potable water, the potential exists for transport of lead to the potable water source. Wells used for potable water within 1/2 mile of a range area should be located. Data on water use from these wells, such as how often they operate, the withdrawal volumes, and the number of users of the well water, should be collected. Of particular interest is the determination of whether or not the wells withdraw groundwater from the same aquifer as the one beneath the range, and an estimate of whether or not water that may be impacted by potential lead leaching could be drawn into a drinking water system. This would all be based on natural flow patterns in the aquifer, productivity and natural characteristics of the aquifer material, and how much water is being withdrawn from the well(s). Similarly, it must be determined if surface waters serving as drinking water sources are near a range. Natural groundwater discharge from range areas to a surface water body has the potential to introduce lead into these supply systems. The data collected are used to identify the potential extent of lead transport and availability to human receptors.

The evaluation of the groundwater in the small arms range area is limited to a study and analysis of existing groundwater data and reports. Recommended data to collect and analyses to perform include

- identification and delineation of local groundwater/aquifers.
- hydrogeological characteristics of identified aquifers. The behavior or movement of the various components of the groundwater flow regime may be inferred based on existing information or application of generalized principles.
- classification and regulatory requirements impacting groundwater based on local use.
- data from groundwater sampling in the range area, if available.

Information sources on wells, water supply systems, and aquifer systems include the installation DPW or environmental offices; local, county, or State health departments; environmental or water resources departments, and the USGS's local Water Resources Office (http://water.usgs.gov/wrd002.html). Typically, contact information can be found in local phone books or Internet sites maintained by these agencies. Most of these data may be available from the installation's environmental office. Previous investigations on the installation conducted by the environmental office have probably gathered information on the delineation of local groundwater/aquifers, hydrogeological characteristics, and regulatory classification. Data may also be available from testing of environmental monitoring or potable water wells installed near the ranges. Typical hydrogeological characteristic data include the depth to groundwater, aquifer thickness, size or aerial extent, permeability, productivity, direction of groundwater movement, and any surface discharge points such as streams. A summary of the groundwater data requirements and potential sources for these data is provided in Table 2-2.

TABLE 2-2. SUMMARY OF GROUNDWATER DATA REQUIREMENTS AND SOURCES

Groundwater Data	Data Sources
Depth to groundwater	Installation environmental office
Aquifer characteristics beneath range; including thickness, size, or aerial extent	Installation environmental office or local USGS Water Resources Office
Aquifer productivity	Installation environmental office or local USGS Water Resources Office
Direction of groundwater movement	Installation environmental office or local USGS Water Resources Office
Location, depth and screened interval of potable water wells within 1/2 mile of range(s)	Installation DPW
Potable water use information	Installation DPW
Surface discharge points (e.g., streams)	Installation environmental office
Surface water use information	Installation DPW or environmental office

DPW = Department of Public Works.
USGS = United States Geologic Survey.

Surface Water Resource Information

Nearby water resources such as streams, wetlands, and ponds can receive storm water runoff from range areas. This creates the potential for degradation of these resources from particulate or dissolved lead and the deposition of sediments from eroded soils. To evaluate the impact of range runoff on surface water resources, the following information should be collected: distance from the range area to the water resource; surface features, such as the slope of the land and surface vegetation cover type (e.g., grasses or forests) between the water resource and the range area; and any direct pathways from the range to the water resource, such as storm water drainage systems. Any other range information, such as other activities or structures that might have an impact on the water resource, should also be identified. The use and regulatory classification of the surface water resources must be determined. If the surface waters near a range serve as recreational or drinking water sources, the potential for human exposure is increased. The data collected are used to identify the potential extent of lead transport and availability to human receptors from surface water. A summary of the data requirements and potential sources of data is provided in Table 2-3.

TABLE 2-3. SUMMARY OF SURFACE WATER DATA REQUIREMENTS AND SOURCES

Surface Water Data	Data Sources
Distance from range area to water resource	Installation environmental office, GIS and USGS
Slope of the land between water resource and range	Installation environmental office, GIS
Vegetation between water resource and range	ITAM office
Storm water drainage systems from range to water resource (e.g., drainage pipes)	Installation DPW
Other structures or activities that may impact water resource	Installation DPW and environmental office

GIS = Geographic Information Systems.
ITAM = Integrated Training Area Management.
USGS = U.S. Geological Survey.

Climate and Precipitation Information

The local climate can influence lead transport by providing a means of physical movement (storm water runoff, wind transport, infiltration, etc.) or by supporting an environment that promotes corrosion of the rounds in the soil matrix. To infer the effects the climate may have, some basic climate information must be collected. Rainfall data, including 2-year, 24-hour rainfall and average monthly rainfall, are needed to evaluate the potential for physical transport through storm water runoff or infiltration. Metals transport pathways may be influenced by the transport distribution of annual precipitation. Estimated precipitation distribution, via evaporation/transpiration, runoff, and groundwater recharge, may be available from the state geological surveys for the areas of concern. The rainfall data, combined with the soil data, may be useful in subjectively evaluating the potential for metals corrosion in the soil. Wind speed data (direction and average speed) by month as well as peak gust speed are needed to evaluate the potential for physical transport through wind (ref 9).

Rainfall patterns can have a significant influence on soil erosion and lead transport. For example, areas of little average rainfall may receive rain in infrequent but intense storms. This is typical in the more arid, sparsely vegetated areas of the southwestern United States. These conditions can promote far more soil erosion and storm water runoff than occurs in areas such as the eastern United States. The eastern portion of the United States receives much more total annual rainfall, but it is typically more evenly distributed throughout the year and storms are generally less intense. Moreover, areas with regular rainfall generally have more vegetation, which greatly aids in controlling soil erosion and storm runoff.

Sources for local climate or weather information include the county Agricultural Extension Agent and local soil surveys, local airports, the USDA Water and Climatic Service at http://www.wcc.nrcs.usda.gov/climate, and the National Climatic Data Center at http://hurricane.ncdc.noaa.gov/CDO/cdo.

Range Use Information

Range use can significantly influence metals transport. The type of small arms range and the type of training conducted on the range affects the distribution and the distance from the firing positions that the rounds impact the ground. Additionally, the type of round used can influence metals transport. These factors influence the physical condition of the rounds (see Range Checks discussion on condition of rounds) which in turn influence the potential for transport either through infiltration, runoff, or aerial transport. The quantity of rounds fired determines the concentration of metals in the soil. As these concentrations rise, the potential for transport may also rise. Maintenance practices on the range can limit or accelerate the transport of metals depending upon other range characteristics as well as the physical condition of the metals present in the range areas. All of this information should be available from Range Control with the exception of historical munitions use information. Documentation of this information has only been required for the last few years. Earlier data may be limited if it exists at all.

2.2.3 Range Evaluation Software Tool (REST) Analysis

A preliminary analysis of lead transport should be conducted with the REST program using the range background information. The REST is a Windows-based software application created by the USAEC to be used as a tool to help range personnel evaluate the potential for lead transport from small arms ranges. It requires the input of site-specific data such as the type and number of rounds fired, soil types, and estimated depth to groundwater. This information is collected and then entered into the program to estimate the potential of metals munitions constituent migration in range areas through a specific pathway: aerial, surface water, or groundwater transport. The REST generates a four-level ranking of the range's overall potential for lead migration. The program generates a numeric score to each of five parameters that contribute to the overall ranking: (1) ammunition mass, (2) corrosion, (3) aerial transport, (4) surface water transport, and (5) groundwater transport. These scores are then combined into an overall numeric ranking and color coded for the range. High overall scores (red) indicate possible lead mobility concerns and the need for further investigation. Conversely, low overall rankings (green) indicate very little or no lead mobility concerns for the range, and investigation or mitigation is unnecessary (ref 9). The relation between the potential for transport and numeric rank and color code is presented in Table 2-4.

TABLE 2-4. RANKING OF REST OUTPUT SCORES

Potential for Transport	Numeric Range	Color Code
High	8 to 10	Red
Medium	6 to 7	Orange
Low	4 to 5	Blue
Very low	1 to 3	Green

REST = Range Evaluation Software Tool.

The scoring system and color code used by REST represents a relative evaluation of lead transport potential that is intended to help range personnel evaluate the need for maintenance operations to mitigate lead migration from the range area. The program does have limitations. Each small arms range is unique and its unique characteristics must be evaluated collectively. The REST helps users learn what to look for, but it is not able to process all of the variables to form a complete picture of lead migration potential. The program is only meant to be a low-cost screening tool used to initially evaluate a range for potential lead migration. Range checks, and possibly environmental sampling and analysis, may need to be conducted to validate the REST analysis. Installation personnel may obtain the REST software and user's manual (ref 9) by contacting the USAEC Army Environmental Hotline at 1-800-USA-3845.

2.2.4 Range Checks

Range checks are a very important part of the evaluation process. During range checks a number of observations must be made and documented. These observations will add the detail necessary to develop an accurate conceptual site model of munitions constituent deposition and transport in the range areas. This level of accuracy cannot be obtained based only on the data gathering activities previously described and use of the REST model. Visual observation of the condition of the munitions debris, land condition, and transport processes is needed to evaluate munitions transport in the environment. When inspecting the small arms range(s), the following observations should be made:

- location of the predominant impact point(s) of the small arms rounds.
- condition of the rounds found at the predominant impact points.
- land/erosion characteristics and storm water flow patterns in and around the predominant impact points.
- surface water proximity, characteristics, and condition downstream of the predominant impact points.

Each of these range check observations is discussed in the following paragraphs.

<u>Location of Small Arms Round Impact Points</u>

The location of where rounds impact on a range or impact area can vary greatly from one range to the next. These variations are dependent on the range design (target location with respect to the firing point), topography, berm location behind the targets (if used to capture rounds), and type of training being conducted. The location of where rounds impact is important to determine since this will be the location where the highest concentration of metals will be located and the starting point for any metals transport that may be occurring from the range area. To evaluate the potential effects of munitions use on the watershed level, the locations of the munitions constituent sources within the watershed must be known. As previously discussed, the watershed represents a true boundary from a functional environmental perspective. By locating the source zone of metals munitions constituents with respect to surface waters, storm water runoff, and shallow groundwater movement within a defined watershed or subwatershed, the possible influences of these sources can be estimated and managed. Conducting an evaluation based solely on constructed firing range boundaries may result in excessive management measures being implemented where natural watershed characteristics may already be attenuating metals transport issues. In addition, the influence of the source of the metal might be missed if the rounds predominantly impact outside of the constructed range area (i.e., the impact area).

Condition of the Small Arms Rounds

The condition of the small arms rounds can greatly influence the ability of the metal to be transported away from its impact point. The physical condition, whether intact, fragmented into pieces, or fragmented into dust-sized particles, will determine the concentration of metals in the soil and the ease in which storm runoff or wind will be capable of transporting the munitions constituents. The intact rounds and rounds fragmented into relatively large pieces will not be easily moved by runoff or wind and present the least human exposure risk, since exposure to metals with these physical characteristics presents a low probability for bioaccessibility. However, dust-sized lead particles (particles $\leq$ 250 µm) can be easily transported by wind or storm water as a suspended solid, and bioaccessibility may become an issue if an exposure pathway exists. In general, 9-mm pistol rounds will stay intact upon impact with the soil and are usually found with little to no deformation or fragmentation. The human exposure risk associated with these rounds in the environment is typically very small. On the other hand, rifle rounds (5.56 mm, 7.62 mm, and 0.50 cal) travel at much higher velocities and will impact the ground with much more force. At relatively short distances (25 m to 150 to 200 m), these rounds will often fragment into very small particle sizes upon impact with the soil. Beyond these distances, there is less fragmentation, resulting in large metal fragments and intact rounds. Based on visual observations, the degree of fragmentation appears to be more a function of distance from the firing point as opposed to the type of soil into which the round is being fired. The rounds that impact the soil within 200 meters of the firing point should probably be the primary focus of the evaluation.

Another factor that affects the condition of the round is the corrosiveness of the environment in which it is placed. Many environmental and physical factors can influence corrosion or bullet metal debris. Rounds that fragment into small, dust-like particles present the worst physical case for corrosion. The higher surface area presented by the small particle size allows corrosion to rapidly release lead (and other metal) ions in dissolved phase. Additionally, these ions typically will bind to soil particles and organic materials, but if the soil type has a low CEC (i.e., sand) then the ions may be free to transport as dissolved-phase lead in either surface runoff or vertically to groundwater in the soil pore fluid. Intact rounds are also susceptible to corrosion. The bimetallic contact between the copper jacket and the lead core of the round can result in an electrochemical reaction occurring, which under the right environmental conditions can result in a rapid corrosion of the lead out of the round. Determination of the exact environmental conditions that promote corrosion of both the bullet debris and the intact bullets requires much research (ref 10). However, field observations may provide some insight to the potential for corrosion. The pH of the soil is one such factor. Theoretically, rounds in soils that have a fairly neutral pH (6.0 to 8.0) should exhibit minimal corrosion. The CEC of the soil can possibly act as either an inhibitor or an accelerator of corrosion. The effects CEC has on corrosion rates are not well defined, but a high-CEC soil is often viewed as a positive situation since the metal ions produced from the corrosion process will likely bind with the soil particles, which should minimize vertical transport to groundwater. However, this continues to present a surface transport risk since the soil particles with metals adsorbed to them can still be transported by storm water runoff as a suspended solid. In addition, anionic salts in the soil (e.g., oxides, hydroxides, carbonates, sulphates, phosphates) may react with the metal ions and form precipitates in the soil or on the surface of the rounds that can either passivate or accelerate the corrosion of the metal. Precipitates (corrosion products) that tightly adhere to the surface of the rounds may passivate or slow metal corrosion by forming a protective layer over the metal (ref 10). Loosely adhering corrosion products may be an indication that the precipitates can be easily removed through either bonding with soil particles or by mechanical means that result in accelerated corrosion of the base metals in the rounds. Without extensive soil and metals speciation analyses, the effect that the naturally occurring anions have on corrosion cannot be determined. These analyses are well beyond the scope of this evaluation. However, visual observation of the bullet debris and intact rounds found at the predominant impact points can allow a subjective evaluation of corrosion potential at these specific locations.

When conducting sight checks, the bullet debris and intact rounds found at the impact points should be inspected for physical condition and corrosion. While the rounds that impact within relatively short distances from the firing point ($\leq$ 200 m) are most likely to exhibit the physical and corrosive characteristics most likely to result in higher transport potential, the rounds impact beyond this distance cannot be ignored. A visual check of the rounds impacting at distances beyond 200 meters should be performed to ensure that the corrosion characteristics or other factors that may have affected the physical deposition of the rounds has not resulted in conditions that are highly susceptible to transport.

Land/Erosion Characteristics and Storm Water Flow Patterns

The characteristics and condition of the land in and around the predominant small arms rounds impact points have tremendous influence on the ability of the metal to be transported away from its impact point. Physical disturbance to the soil caused by the rounds impacting the soil is usually a minor factor in the ability for the soil and lead to be transported from the impact point. Normally, this disturbance and distribution of bullet debris is localized to an area near the impact point. Typical impact dispersion can be found at the bottom of the berm, on the berm face, or within a short distance behind the berm. The characteristics of the land in and around these impact points have the most effect on transport potential. The range check should focus on the following characteristics as a minimum:

Soil Characteristics (Sand, Silt, Clay, Organic Content, Etc.) - The larger soil particles (e.g., sand) have a lower CEC and are highly permeable. Impact points with this soil characteristic may present a condition conducive to infiltration and potential transport to groundwater. The small soil particles (e.g., clay) usually have a high CEC and a low permeability. Impact points with this soil characteristic will usually have a low potential for transport to groundwater because the soil density is higher and thus limits rain infiltration. However, clay may have a high potential for overland transport to surface water because the clay particles suspended in the runoff may have lead ions bonded to them. Typically, the soil characteristics actually found in the field will be a mixture of sand, silt, and clay that will possess its own unique permeability, CEC, pH, etc. Permeability may be fairly uniform between the ground surface and the groundwater layer, or a stratification of permeable and impermeable layers might provide a physical barrier to lead transport to groundwater. Other characteristics of the soil (e.g., organic content, pH, nutrient content) can have any number of effects on the soil's permeability, corrosiveness, ionic bonding capabilities, etc., that could mitigate or accelerate lead transport in either the soil pore fluid or the runoff. All of these factors should be considered along with the background data when subjectively evaluating transport potential.

Slope - The effect of topography, or the slope of the soil in and around areas in which the rounds are impacting, is another important factor in potential transport. Generally, soil erosion and transport increases with slope length and height.

Vegetation Cover - Vegetative cover mitigates erosion in several ways. It reduces the energy of the rainfall striking the soil surface by intercepting the raindrops before they hit the soil. The raindrops will fracture into smaller drops with less energy, drip from the leaf edges, or travel down the plant stems to the ground (ref 11). The erosion effect caused by raindrop impact on the soil is illustrated by the pronounced pedestal erosion seen where rock fragments, spent bullets and fragments, or other debris shield the underlying soil from the direct impact of rain. A pedestal is created under the shielding object by the erosion of surrounding, exposed soils (fig. 2-3). Vegetation also stabilizes the soil surface to counteract the scouring potential of overland flow and decreases the erosive capacity of the flowing water by reducing its velocity. The shielding effect of plant cover is augmented by roots and rhizomes that hold the soil, improve its physical condition, and increase the rate of infiltration, further decreasing runoff. The ability of the vegetation around the predominant impact points to mitigate erosion effects should be subjectively evaluated during the range checks.

Figure 2-3. Pedestal erosion.

Evidence of Erosion - In addition to the pedestal erosion depicted in Figure 2-3, any other evidence of erosion should be identified during the range checks. Erosion in and around the predominant impact points, as well as in the storm water runoff paths from these points, must be investigated. Evidence of rill formation and sediment deposits in these areas must be identified. It must be determined if an on- or off-range area exists where eroded soils are being substantially deposited as layers of sediments or if other important resources such as surface water bodies are likely to be impacted by soil erosion and sediment deposition. Soil erosion on an unvegetated swale is shown in Figure 2-4. The direction of flow can be determined by observation during a rain event or by noting the fan pattern that is left by the flowing sediments. The fan will widen as the sediments travel downhill (see arrows). A vegetated swale showing sediment deposits on the upgradient side of the vegetation is shown in Figure 2-5. The vegetation acts as a filter trapping the suspended solids as the water flows through. The direction of flow can be determined based on the accumulation of sediments upgradient of the vegetation.

Figure 2-4. Swale showing sediment transport.

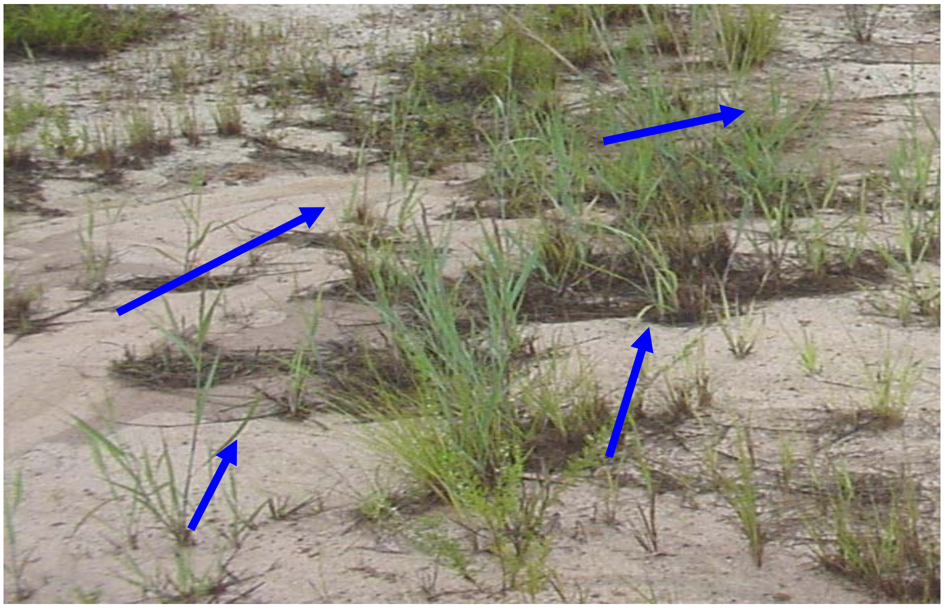


Figure 2-5. Swale showing sediment deposition upgradient of the vegetation.

Storm Water Runoff Paths - Storm water flow paths in and around the predominant impact points will have a major impact on surface transport of the munitions metals. Areas disturbed by the impacts of the rounds are susceptible to erosion. If these areas lie where storm water runoff will flow over, then the likelihood of metals transport, at least from the immediate area of the rounds impact, is very high. Range checks should identify storm water flow paths in or near these areas, with particular attention paid to sediment transport from these areas as described in the preceding paragraph. Any storm water management methods currently in place should be identified, and their effects on sediment transport from the predominant impact points should be subjectively evaluated. Storm water management methods may include structures such as drainage culverts, piping, swales, or detention ponds. The ability of these methods to adequately manage typical storm water runoff volumes from the range should be gauged. In addition, the actual design capacity of the methods, particularly structures such as water retention ponds, should be documented. Engineering plans from an installation's DPW or facilities office should be a good source of information and specifications on constructed storm water management systems. For areas with no engineered structures or formal management plans, the range check may be able to determine how and where storm water drains. The range check should be conducted by evaluating surface topography as well as identifying surface drainage features. By recognizing the slope of the land surface, the direction in which runoff water will flow and the nature of the flow (e.g., sheet flow, channel flow, etc.) can be determined. A typical depiction of storm water flow is shown in Figure 2-6.

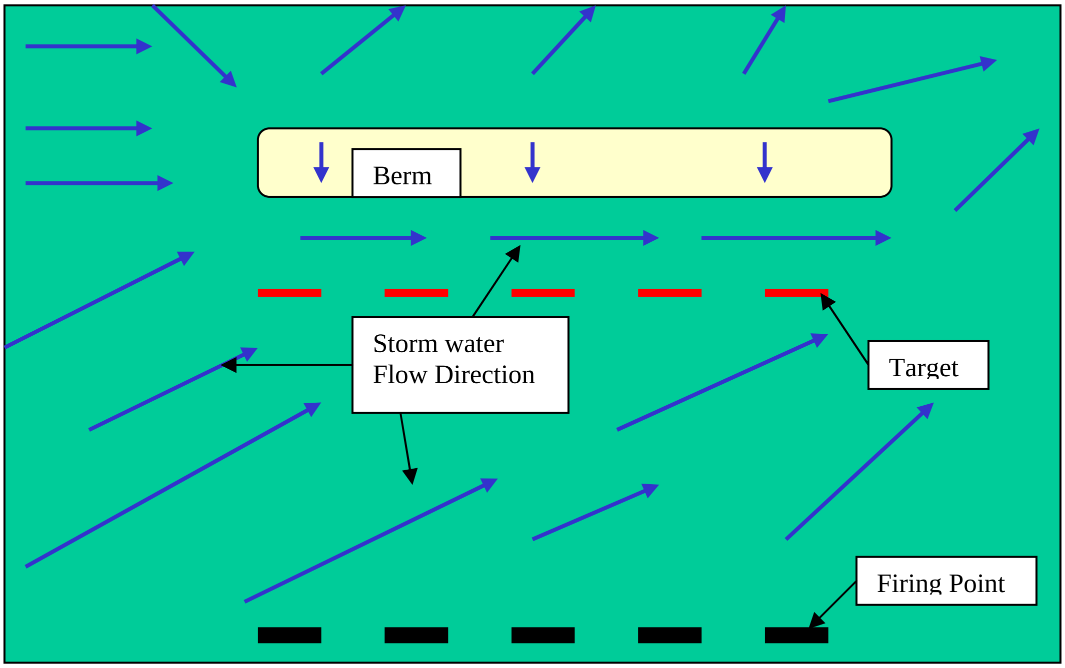


Figure 2-6. Storm water flow pattern over and around a berm.

<u>Surface Water Resource Proximity, Characteristics, and Condition</u>

The distance to nearby water resources such as streams, wetlands, and ponds from the predominant impact points must be identified. In conjunction with the range observations described in the preceding paragraphs, the potential for munitions metals to reach these resources should be subjectively evaluated. The focus of these checks is to evaluate the potential for degradation of these resources from particulate or dissolved lead and the deposition of sediments from eroded soils.

The condition of the surface water resources also must be documented. An evaluation of stream health can shed light on the overall erosion and sediment transport issues that may degrade water quality and provide insight into potential methods of mitigating these issues. Nearby streams that may serve as storm water collection points should be surveyed for signs of erosion in the channel side banks. Excessive storm water runoff volumes or flow velocities can erode channel banks. Erosion of the banks further contributes to water quality degradation. An intermittent stream into which runoff from a range drains is shown in Figure 2-7. Gully erosion, bank failure, and pools of water containing suspended sediments (foreground) are evident. Riprap was installed in the stream to help prevent erosion, but its placement has probably contributed to the degraded condition shown in Figure 2-7. A visual stream evaluation protocol available from the USDA provides a guide to conduct a basic evaluation of stream health (ref 12). Conducting this evaluation in conjunction with the overall small arms range evaluation is recommended. As a minimum, the channel condition, hydrologic alteration, riparian zone, bank stability, and water appearance aspects of the USDA evaluation should be conducted.

Figure 2-7. Intermittent stream bank instability.

2.2.5 Conceptual Site Model Development

A conceptual site model is not a computer algorithm that estimates lead transport or soil erosion potential. It is simply a brief and succinct written description of the conditions in the range area, as they are understood, combined with an evaluation of those potential metals transport and potential human exposure. The conceptual site model pulls together and summarizes all information collected during the watershed delineation, background data collection, REST analysis, and range checks. It states the current understanding and assumptions regarding the range and the munitions constituents of concern at the range, how they may be migrating, and where they are going. The model also subjectively evaluates the potential for human exposure to the munitions constituents in the transport pathways. The conceptual site model is developed on a watershed or subwatershed scale. An example of a conceptual site model is provided in Appendix B.

The conceptual site model is used to determine the need for BMPs to control metals transport. If the potential for off-range transport or human exposure is not indicated by the model, then no further investigative actions need to be performed nor do BMPs need to be implemented based on current range use and condition. Data collected in the Step I evaluation can be used at the range manager's discretion to identify improved range and training area maintenance practices that may ensure sustained range availability. However, if the evaluation indicates that metals transport or human exposure potential exists, then BMP methods should be implemented. BMP implementation should be limited to the minimum required to address the operation, site-specific condition, range design feature, or maintenance procedure that most affects metals transport. The data collected during Step I of the range evaluation should provide sufficient information to select or design effective BMPs. In addition to implementing BMPs, the installation's environmental management should be consulted to determine whether further study of metals transport is necessary. In order to support this decision or to support BMP implementation and performance monitoring, additional field data collection consisting of limited sampling of identified potential transport pathways may be conducted at the installation's discretion. General guidance for this additional data collection is provided in section 2.3.

2.3 Step II – Additional Data Collection (Optional)

Additional data collection may be conducted, at the installation's discretion, as a follow-up to the Step I range evaluation to

- further refine the conceptual site model, or
- support design and implementation of BMPs as well as providing limited baseline data for determining BMP performance, or
- support environmental management's consideration of whether to conduct comprehensive environmental investigations of metals transport or exposure risk assessments.

Step II data collection efforts will typically focus on the transport pathways identified by the conceptual site model as having active metals transport or potential human exposure concerns. This data collection effort is not intended to support an environmental site characterization. Its purpose is limited to one or more of the objectives identified above.

2.3.1 Sampling Plan

A formal sampling plan should be developed for the data collection effort that clearly and concisely states all aspects of the effort. A formal plan allows all individuals or organizations involved a chance to review, comment, and understand the task. It also serves as a permanent record of the sampling activities. During the planning stages, thorough coordination with range personnel, training schedulers, safety office personnel, and the sampling team should be accomplished to prevent scheduling conflicts and address potential safety issues. The sampling plan should include the following information as a minimum:

- sampling objectives (why sampling is being performed and what media will be sampled).
- who will be performing the sampling (organization(s) and individuals involved).
- where samples will be collected and the approximate number of samples.

- sampling methods and equipment to be used.
- sample analysis methods.
- quality control (QC) and quality assurance (QA) measures.
- health and safety requirements for field sampling activities.

Sample plan development should follow the general guidelines found in Chapter 9 of USEPA 530/SW-846 (ref 13). Although this guidance was developed for waste site sampling, it should support the data collection efforts for range areas. Additionally, the Army Sampling and Analysis Plan available from USAEC (ref 9) provides guidance for collecting data from metals transport pathways in range areas. Sampling plan development and the conduct of field sampling should be coordinated by the installation's environmental office. The sampling plan information listed above is briefly discussed in the following paragraphs.

Sampling Objectives

The reason for conducting the sampling and the limited scope of the investigation must be clearly stated in the sampling plan. As previously discussed, sampling can be conducted for several reasons: (1) to further refine the conceptual site model, (2) to support design and implementation of BMPs as well as providing limited baseline data for determining BMP performance, or (3) to support environmental management's consideration of whether to conduct comprehensive environmental investigations of metals transport or exposure risk assessments. This data collection effort must be understood to be part of an evaluation to support the development of range sustainability management options for the small arms ranges; it is not to be considered part of an investigation for environmental regulatory purposes.

The media (soil, sediment, groundwater, surface water, storm water, air) requiring sampling will be determined by the conceptual site model. For example, if the evaluation indicates that only groundwater is expected to be impacted from metals transport, then groundwater and possibly subsurface soil samples may be collected to address the issue. The other media will not require sampling since their potential as a transport risk was determined to be low. The sampling plan objectives should clearly state what media is being investigated and should use the conceptual site model previously developed to limit the scope of the investigation.

Sampling Execution

The person or persons responsible for executing the field sampling effort should be identified. To ensure that correct sampling and field documentation procedures are followed, the installation's environmental office or contractor should be responsible for executing the sampling plan.

Sampling Strategy

The sampling strategy will identify the locations and the number of samples to be collected to achieve the stated sampling objective. In the following paragraphs, a suggested general strategy for each media is identified for use as a guide in developing this part of the sampling plan. By using these guidelines and the conceptual site model, the locations for sampling can be selected. The number of samples to be collected should be determined based on the specific data quality objectives established to meet the data collection objectives. Data quality objectives are further discussed in the QA/QC section. Additionally, other factors can limit data collection activities. These include range training schedules, personnel availability, and funding constraints. A summary of suggested media sampling types and frequency to support the conceptual site model refinement or BMP implementation objectives is presented in Table 2-5. Refer to the Army Sampling and Analysis Plan available from USAEC (ref 9) for additional guidance on collecting samples from metals transport pathways. Sample requirements and frequency necessary to support environmental management decisions on future investigative actions will be specific to the transport mechanism and site issues (e.g. exposure potential, water quality considerations, etc.) and should be determined by the installation's environmental office. Existing data on background metals concentrations should be obtained or background sampling should be conducted for comparison with range related media sampling. This is done to ensure that natural metals do not skew the interpretation of the munitions constituent transport data.

TABLE 2-5. MEDIA SAMPLING SUMMARY

Environmental Media	Duration of Sampling at a Given Location	Sample Type	Type of Information Obtained
Soil	1 sampling event	Surface soil composites, cores in areas of concern	Absence or presence of munitions constituents and concentrations; difficult to distinguish between current or historical contamination.
Air	Up to 1 year, monthly retrieval and analysis of samples	Monthly composites	Current munitions constituent transport and Concentrations.
Groundwater	1 sampling event	Discrete samples	Absence or presence of munitions constituents and concentrations; difficult to distinguish between current or historical contamination.
Surface water	1 sampling event	Grab samples	Absence or presence of munitions constituents and concentrations; difficult to distinguish between current or historical contamination.
Sediments	1 sampling event	Grab samples, composites	Absence or presence of munitions constituents and concentrations; difficult to distinguish between current or historical contamination unless very confident that sediments are freshly deposited from range areas.
Storm water runoff	Up to 1 year, minimum average 1 storm event per month	Discrete or composite, time weighted	Current munitions constituent transport and concentrations.

Soil. Soil sample collection to support conceptual site model refinement or BMP implementation objectives are discussed in this section. Guidance for environmental management investigation decisions should be developed by the installation's environmental management. Generally, soil sampling on ranges is not needed unless metals concentration data is necessary to support BMP implementation. Soil sampling would usually be conducted in transport pathways if desired to refine the conceptual site model. On-range sampling is generally not needed for this purpose (with the exception of potential infiltration to groundwater) since it is accepted that metals will be in the soil at the predominant impact points at relatively high concentrations. Determining metals concentrations in these areas generally do not provide much information that would define transport mechanisms or potential.

Soil sampling for model refinement or BMP implementation are recommended to be limited efforts that basically determine the presence of range use related munitions constituents. An accurate quantitative characterization of metals concentrations in soil is generally not needed for these purposes. If the conceptual site model indicates that a transport mechanism exists then soil sampling in potential transport pathways may provide a confirmation of that transport mechanism. The transport mechanisms that may warrant soil sampling include aerial transport, transport to groundwater, and transport by surface runoff (storm water).

Aerial or wind-blown transport of lead-contaminated dust may occur if the range soil has high silt content, little vegetation, high wind, and no windbreaks. If aerial transport by windblown dust is suspected, then composite surface soil samples should be collected from locations downwind of the predominant impact points on the range. In this case, the soil sampling results may support data collected from active windblown dust sampling to prove or disprove aerial transport as a means of lead migration at a range. Surface soil sampling locations should be collocated with samplers for collection of active windblown dust samples (ref 9).

If transport to groundwater is suspected, then soil core samples should be collected from the areas where the soil lead concentrations are the highest (the predominant impact points on the range). Soil cores can be collected in coordination with the installation of shallow groundwater wells, as described in the following groundwater sampling section.

If storm water transport is suspected, then composite surface soil or sediment samples should be collected from locations downgradient in the runoff paths from the predominant impact points on the range. Soil samples should be collected from the runoff paths just prior to entering surface water resources (e.g., streams, wetlands) as a minimum.

Soil sampling guidance is available from sources such as the USEPA or the United States Army Corps of Engineers (USACE). The installation environmental personnel can provide specific guidance for the collection of composite surface soil and soil core samples based on the soil type and sampling tools available. Some general recommendations are that the surface samples be collected at no more than 1 to 2 inches in depth and that random composite samples be taken to produce an average soil metals concentration for a given area. Soil samples should be analyzed using USEPA SW-846 Method 6010B (ref 14).

Air. Air transport of lead at firing ranges may account for the movement of more lead quantities than is generally perceived. Bullets fired into impact berms generate dusts of fine soil particles that can be easily seen, particularly during heavy use of a range. These dusts likely contain some quantity of lead from fragmenting bullets. General wind erosion on dry, bare soils is also a potential transport mechanism for fine particles containing lead. Fine dusts are one of the significant human health concerns associated with lead; however, these dusts typically do not travel far from the immediate range area before being deposited back on the soil surface. The Army Sampling and Analysis Plan (ref 9) discusses studies by Merrington and Alloway (1994) that suggest these types of dusts would travel, at most, 300 meters from an impact berm, and that sampling at a distance of 150 meters from a berm in the predominant wind direction would likely provide adequate information on the quantity of aerial transport of lead from a range. A generalized sample location scenario is shown in Figure 2-8. If little or no lead is found at this distance from aerial deposition, it is reasonable to assume that even smaller amounts or none is being deposited at further distances. In addition, the 300-meter aerial travel distance is likely to be under ideal conditions (i.e., flat, open land with no obstructions to dust travel). Any significant stand of trees or woods would likely serve as a windbreak or filter, blocking airborne lead dusts from further travel. In such a case, sampling just in front of the woods would be appropriate if aerial transport is considered a potential concern.

Accounting for the relatively short travel distances of range dusts, sampling for aerial transport of lead is not generally recommended. Dusts probably do not leave the range area. Some scenarios that may warrant performing air sampling are

- range areas where the soil has a high silt content, little vegetation, high wind, and no windbreaks, and
- a range is immediately adjacent (less than 300 m) to an installation boundary, or
- range dusts could potentially reach a human receptor (such as housing or surface water resources) located immediately adjacent to the range boundary or within 300 meters of the predominant impact points on the range.

If the conceptual site model suggests the potential for aerial transport, a procedure (sampling procedures, materials, etc.) for collecting air dust samples of active aerial transport of lead has been outlined in detail in the Army Sampling and Analysis Plan (ref 9). The dust samples should be analyzed using USEPA SW-846 Method 6010B (ref 14).

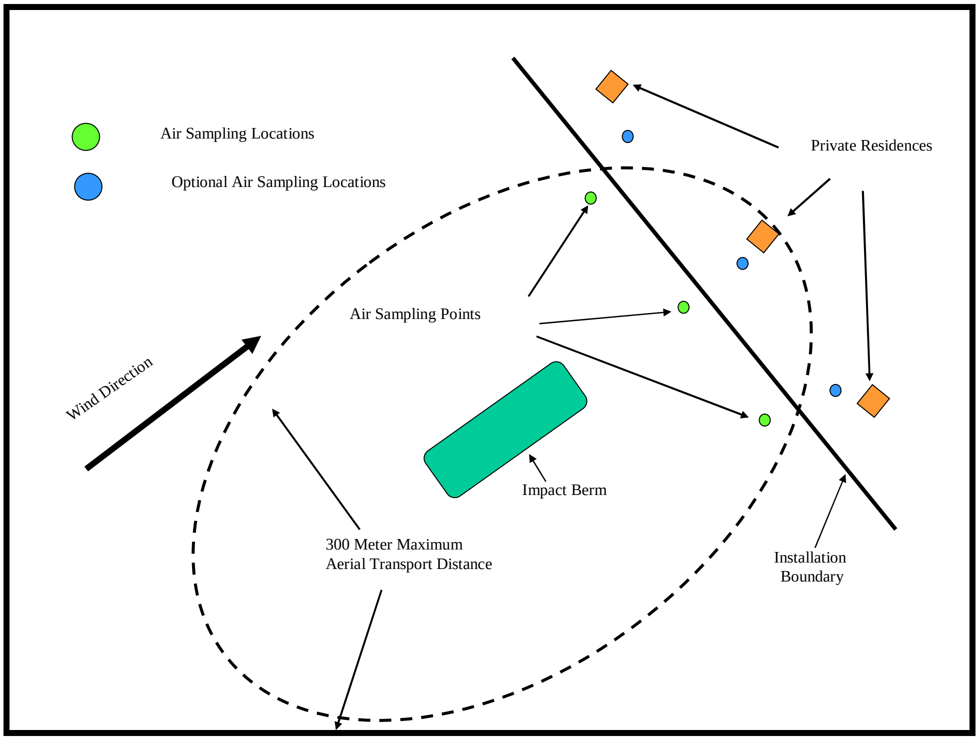


Figure 2-8. Generalized aerial transport sampling scenario.

Groundwater. If the conceptual site model suggests that there is a potential for metals infiltration to groundwater and this transport may result in the potential exposure to humans from the nearby use of groundwater wells, then sampling is recommended. This groundwater concern is most likely to occur if humans are using shallow extraction wells for potable water, such as those that may be providing potable water for range buildings or private wells near the range/installation boundary.

If data collection for development of the conceptual site model identified existing monitoring wells or potable water wells in or near range areas that meet data needs (proper location, depth, correct aquifer, etc.), then these wells should be sampled and the results evaluated for metals content. New groundwater wells may be expensive to install and in some cases requirements may exist to continue long-term monitoring once they are installed, so the need for this data should be thoroughly discussed with the installation's environmental management prior to taking action. If privately owned wells are targeted for sampling, permission must be obtained from the property owner prior to sampling. Approval for any proposed off-installation sampling should be obtained from and coordinated through the installation legal office, Command office, and public affairs office as a minimum before approaching private property owners about sampling tap water or wells. As an alternative to sampling privately owned wells, new wells can be installed on the installation at the installation boundary, or sampling by direct push sampling methods (as described below) can be used to collect this information. When sampling wells at the tap or faucet, the type of plumbing in the system (e.g., lead pipes, lead solder) and the type of water conditioning systems that may have an impact on the water quality/analysis should be documented.

Groundwater sampling methods such as the direct push technologies (e.g., Cone Penetrometer, Geo-Probe, Hydro Punch) that hydraulically insert sampling probes into the ground and then retrieve a groundwater sample are recommended if feasible for the site. These technologies allow for quick sample collection at many locations, generate very little waste, and are well suited to the shallow depths at which most groundwater data collection will likely be performed. Collection of soil cores from the unsaturated zone can be coordinated with the insertion of the sample probes to obtain a profile of metals concentrations in the soil column collocated with the groundwater sampling points in the suspected metals source areas. Sample locations should include one sampling point in the predominant round impact point in the range area and a minimum of two sampling points downgradient of this point spaced at approximately 100-meter intervals or before reaching the installation boundary, whichever is closest. If a sampling point upgradient of a small arms range or other range related impacts can be located, then a sample location should be established there for comparison to nonrange impacted water quality data.

Sample preservation and analyses should be in accordance with the appropriate analytical methods. The analyses of groundwater samples should include total and dissolved lead concentrations and hardness. The metals concentration analyses should be performed in accordance with USEPA Method 200.8 (ref 15). The hardness analysis should be performed in accordance with Standard Method 2340-B (ref 16).

Surface Water. Surface water quality (streams, ponds, etc.) is primarily governed by the quality of storm water runoff, the shallow groundwater discharge that provides the base flow to the surface water resource, and the direct or indirect deposit of lead into the water body. Sampling the base flow of a surface water resource may provide some insight into the effects of legacy lead (the cumulative effects that lead has had on the water quality of the watershed), i.e., a combined effect of sediments that may have been deposited by past erosion from the ranges, the quality of the shallow groundwater if lead is suspected to have reached the groundwater layer, and in some cases the direct deposit or impact of the fired rounds into the surface water body. Attempting to differentiate the effects these individual factors have on surface water base flow is well beyond the scope of the evaluation; however, knowing the combined effect provides some insight into the overall watershed health as it relates to small arms range use.

Sampling of the base flow is recommended prior to the initiation of a storm water monitoring program. The base flow sampling will provide a baseline of current water quality that reflects past and ongoing lead migration without a lead input from storm water transport. Storm water monitoring results can then be compared with this baseline to gauge the ongoing effects, if any, that current range use and maintenance practices have on both storm water quality and general surface water quality.

Sampling of surface water resources should consist of grab samples. The samples should begin from a downstream point where either a potential receptor may be encountered or at the installation boundary, and proceed upstream to points where the surface water resource may potentially be influenced by lead (on or near the range). A generalized surface water sampling location scenario is shown in Figure 2-9.

Sample preservation and analyses should be in accordance with the appropriate analytical methods. The analyses of surface water samples should include total and dissolved metals concentrations, total suspended solids (TSS), and hardness. The lead concentration analyses should be performed in accordance with USEPA Method 200.8 (ref 15). The hardness analysis should be performed in accordance with Standard Method 2340-B (ref 16). TSS analyses should be performed in accordance with Standard Method 2540-D (ref 17).

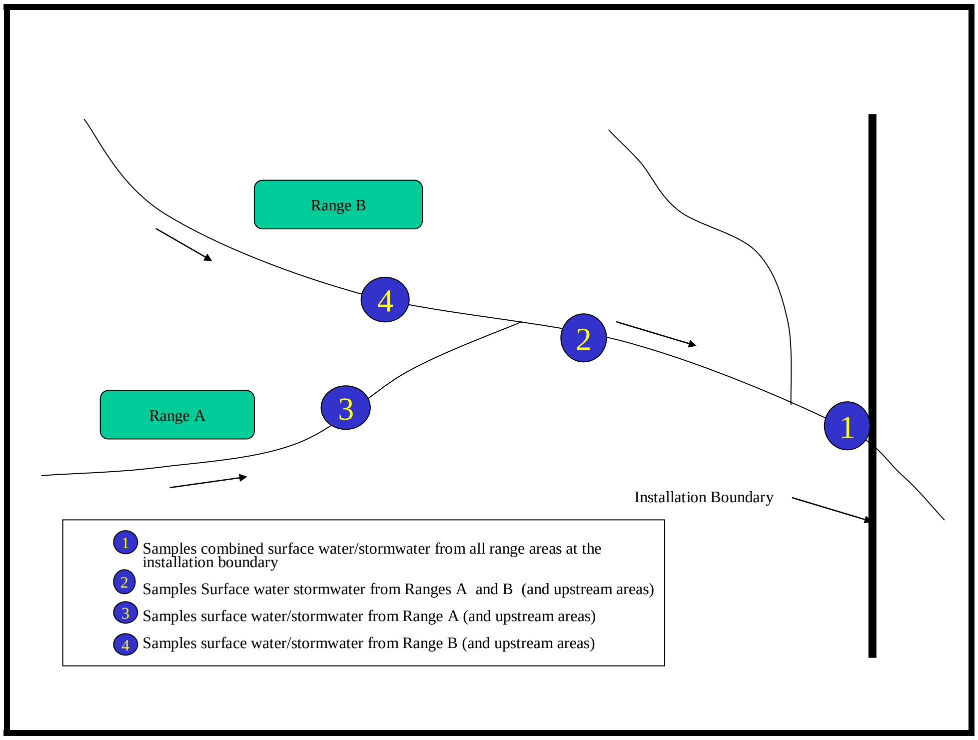


Figure 2-9. Generalized surface water and storm water sampling scenario.

Sediments. Sediment samples collected from streambeds or from other surface water resources will not provide a clear indication of current lead movement. The metals concentrations in these sediments may have been transported years ago when old range use or maintenance practices resulted in lead migration. The collection of storm water samples is the only sampling that provides an indication of current runoff transport characteristics; however, sediment sampling is recommended if storm water runoff is suspected to be an active transport mechanism. Sediment samples should be collected at locations collocated with the base flow sampling of the surface water resources to provide additional insight to the overall watershed health as it relates to past, and possibly present, small arms range use.

Sediment sampling may also be useful to evaluate the performance of sediment removal and erosion control structures. These structures may already be installed in some range areas to mitigate the impact of suspended solids on surface water resources. Samples should be collected from the influent and discharge pipes of storm water retention ponds to evaluate the effectiveness of the control structure.

Sediment sampling is typically performed by obtaining a grab sample. Discrete or composite grab samples can be taken. Sediment sampling guidance is available from sources such as the USEPA or USACE. The installation environmental personnel can provide specific guidance for the collection of sediment samples. Some general recommendations are that the surface samples be collected at no more than 1 to 2 inches in depth. Sediment samples should be analyzed using USEPA SW-846 Method 6010B (ref 14).

Storm water. Storm water quality is commonly monitored as a measure of the impact of land use practices on surface water quality within a watershed. Storm water runoff from range areas represents the most likely mechanism for metals residues and eroded soils/sediments to be transported off-range. Storm water runoff has the potential to (1) carry large volumes of munitions constituents as suspended solids, (2) carry the munitions constituents the farthest distances, and (3) directly impact human health. Runoff waters can carry solid particles of metals or metals adsorbed to soil particles as part of the suspended sediment load. Runoff waters can also carry dissolved metals within the water, although dissolved metals are usually a very small percentage of the total metals transported in storm water runoff. Storm water runoff volumes are highly variable, as is the amount of sediments or metals found in the runoff. As a result, multiple sampling events are often required to attempt to determine the effects of rainfall intensity and seasonal variations on the runoff quality.

Possible locations for sampling runoff water may have been identified during the initial range evaluation. Existing structures, such as drainage pipes or culverts that concentrate the flow of water and provide adequate depths or volumes, are good places to sample. Outfall or discharge pipes of structures such as storm water retention pounds are also excellent places to sample to determine metals and sediments concentrations that may still be migrating beyond these control points. Natural stream channels should be included as sampling locations near range storm water runoff entry points and downstream of the range areas to gauge the natural attenuation effects that sediment settling, dilution, and dispersion have on water quality prior to reaching potential human receptors.

A storm water sampling program is recommended to be conducted for at least 1 year to sample an adequate number of storms and their runoff. Runoff water quality is highly variable and depends on factors such as seasonal variations in rain and range conditions and variations in training area use.

Storm water samples can be taken by automated samplers programmed to collect samples based on flow volumes or at specific time intervals during the increased water flow associated with storm runoff. Two types of samples should be collected at each sampling location: (1) a first flush sample, and (2) a time-weighted composite sample. The first flush sample is taken at the beginning of storm water runoff into the surface water resource to determine the lead and suspended solids concentration caused by this initial flush of water over the range areas. This first flush runoff is believed to potentially have the highest concentrations of sediment and metals. The time-weighted composite sample is a discrete sample taken at specific time intervals during the increased water flow volume associated with a storm. A sampling interval such as once every 10 to 15 minutes is suggested. The interval can be adjusted up or down based on site-specific conditions. This sampling attempts to capture the overall water quality during the storm.

Sample preservation and analyses should be in accordance with the appropriate analytical methods. The analyses of storm water samples should include total and dissolved metals concentrations, TSS, and hardness. The metals concentration analyses should be performed in accordance with USEPA Method 200.8 (ref 15). The hardness analysis should be performed in accordance with Standard Method 2340-B (ref 16). TSS analyses should be performed in accordance with Standard Method 2540-D (ref 17).

QC and QA

General sampling and analysis QC and QA requirements are identified in the referenced analysis methods specified for each transport media. These QA/QC requirements may be used as guidelines when developing data quality objectives for the data collection objective(s). The data quality objectives will be dependent upon the purpose of conducting the additional data collection. The data collected for conceptual site model refinement or BMP implementation support will be used in a qualitative manner. Basically, the presence of the munitions metal constituents is all that is necessary to support these objectives. As a result, high data accuracy and precision is not necessary and limited sampling as described above can be performed. In some cases, BMP implementation may require higher data accuracy and precision to effectively implement the BMP, but this will be dependent upon the specific BMP being applied and site conditions. Caution is recommended in the interpretation of the data from these small or limited number of samples since these data sets will not stand up to statistical analysis and may be inadequate to determine even the presence or absence of significant site-related releases.

Data collected to support environmental management decisions on the need to conduct follow-on environmental characterization or risk assessment investigations needs to meet quantitative use requirements. High data accuracy and precision is needed for comparison to established regulatory or water quality criteria. These accuracy and precision requirements will need to be determined on a case by case basis dependent upon the transport mechanisms and potential exposures identified in the conceptual site model. The installation's environmental management needs to determine these requirements and design the sampling efforts to meet those requirements.

<u>Field Sampling Health and Safety Plan</u>

Health and safety issues should be addressed for the sampling effort. Those drafting and performing the sampling plan should consult with the installation's safety office to address appropriate requirements. A formal health and safety plan or risk evaluation may be required. The installation's safety office should be able to provide information required within such a plan, typically, known site safety hazards and precautions (e.g., unexploded ordnance, poisonous snakes, ticks), appropriate personal protective equipment (PPE), emergency phone numbers, local emergency medical facilities, responsible personnel, etc.

2.4 Step III – BMP Implementation Requirements

At the completion of Step I and Step II (if performed) the next course of action is to determine whether BMP methods in addition to current maintenance and management practices need to be implemented in the range areas. If one or both of these steps indicate that metals transport is potentially occurring and this transport may result in either human exposure or constituent transport beyond the installation boundaries, then BMPs should be implemented to control the active transport pathway. If these conditions do not exist, then no additional maintenance or management actions are required. Additionally, if the potential for metals transport that may result in either human exposure or constituent transport beyond the installation boundaries exists, then the installation's environmental management should be notified to determine when they should initiate characterization or risk assessment actions.

If changes to range maintenance or management practices are determined to be needed, then the BMP selection and implementation guidance provided in section 3 of this manual should be followed to guide the successful selection, application, and maintenance of methods to control munitions metal constituents in the small arms range areas.

3. Small Arms Range Sustainment Method Selection and Implementation Guidance

The implementation of environmental sustainment (BMP) methods, if appropriate, at an operational small arms range should be based on the results of the range evaluation of the potential fate of the lead being placed on the range. The method(s) selected should be limited to the minimum required to address the operation, site-specific condition, range design feature, or maintenance procedure that most affects lead risk on the range or lead transport. These range sustainment methods may involve the prevention of lead migration, pollution prevention, or lead removal methods. These methods may be applied in a complementary or cumulative way to achieve the most successful storm water runoff quality improvement results. Following are BMP method categories that may be used to resolve potential range use environmental issues.

Prevention of Lead Migration

- operational changes
- vegetative solutions
- storm water management
- berm design and structural enhancements
- geosynthetic materials
- soil amendments

Pollution Prevention

- green ammunition
- bullet traps

Lead Removal

Each of these BMP method categories will be discussed in detail in the following sections of this manual. The following information will be discussed for each BMP:

- BMP description
- benefit
- applicability
- limitations
- implementation guidance

- maintenance requirements
- cost elements

Many available sources of information provide design and installation guidance for storm water and erosion control. Many of the vegetative and storm water management BMPs identified in this manual were copied or adapted from these sources. The primary reference for several sections of the vegetative and storm water BMPs is the Sediment and Erosion Control Planning, Design and SPECification Information and Guidance Tool (SEDSPEC) Web site published by the Engineer Research and Development Center - Construction Engineering Research Laboratory (ERDC-CERL). The design criteria of several of the BMPs were copied directly from SEDSPEC (ref 18). For additional information on the BMPs discussed in this manual and the other BMPs that may or may not be applicable to small arms ranges, the sources identified in Table 3-1 should be consulted.

TABLE 3-1. BMP METHOD INFORMATION SOURCES

BMP Source	Controlling Organization	Web Address
SEDSPEC	ERDC - CERL	http://owww.cecer.army.mil/ll/sedspec/index.cfm
National Menu of Best Management Practices for Storm Water Phase II	USEPA - Office of Water	http://cfpub.epa.gov/npdes/stormwater/menuofbmps/menu.cfm
Storm Water Design Manual Toolbox	Storm water manager's resource center	http://www.stormwatercenter.net
USDA Planning and Design Manual for the Control of Erosion, Sediment, and Storm water	USDA	http://www.abe.msstate.edu/Tools/csd/p-dm/index.html
Indiana NRCS Engineering Design Spreadsheets	NRCS	http://www.in.nrcs.usda.gov/technical/engineering/EngSpreadSheets.html
Urban Small Sites BMP Manual	Metropolitan Council	http://www.metrocouncil.org/environment/Watershed/bmp/manual.htm

CERL = Construction Engineering Research Laboratory.
USEPA = US Environmental Protection Agency.
ERDC = Engineer Research and Development Center.
NRCS = National Resources Conservation Service.
SEDSPEC = Sediment and Erosion Control Planning, Design and SPECification Information and Guidance Tool.
USDA = U.S. Department of Agriculture.

Before proceeding to the BMP information, consideration of how to select the appropriate BMP method, based on the environmental issues and range conditions identified in the evaluation and the general range design will be discussed. Then, each BMP method category and its associated BMP methods will be discussed individually.

3.1 BMP Selection Process

This section outlines a process for selecting the best BMP or group of BMPs for a small arms range training area. This four-step process progressively screens the BMPs appropriate for training area suitability; metals transport mechanism suitability, physical range characteristic suitability (ref 11), and an economic or trade-off analysis.

Step 1. The BMP list is screened appropriate for its suitability for use on specific types of small arms ranges and impact areas. The screen should be appropriate for the location where the small arms rounds predominantly impact. If they impact on the range or in an impact area, the specific range or impact area type should be determined (table 3-2) to identify BMP(s) applicable to that type of range.

Step 2. The BMP list generated from Step 1 is then screened using Table 3-3 to determine which BMP(s) will address the predominant metal transport mechanism active in the area of concern. At the end of this step, the BMP options can be reduced to a manageable list for further consideration that specifically addresses the transport mechanism(s) present at the predominant impact points in the range area.

Step 3. The BMP list generated from Step 2 is then used to build a third table in which the remaining BMPs are screened against the site-specific physical characteristics present in the area of concern. These site-specific physical characteristics were identified in the range evaluation process and documented in the conceptual site model. Some of the basic site characteristic parameters that may be used to conduct the site suitability screen are presented in Table 3-4. The parameters identified in Table 3-4 are an example only. Site characteristic parameters may be changed in the table to suit the area of concern based on the conceptual site model. Parameters that appear to have a significant influence on metals transport or are suspected to place a limitation on BMP method application should be used. Review the limitations sections of the BMP methods to identify potentially limiting parameters. The BMP methods can then be ranked based on their ability to mitigate the predominant transport mechanisms with respect to the site conditions in the range area. At the end of this step, the BMP options will have been reduced to only the specific BMP methods capable of addressing the transport mechanisms under the site-specific conditions present at the predominant impact points and transport pathways in the range area.

Step 4. The final BMP list generated from the Step 3 screen should then be subjected to a trade-off analysis to determine which method(s) can be feasibly implemented to meet range management goals versus the economic cost of implementing and maintaining the BMP. The economic analysis of the feasible BMPs should be conducted in accordance with the Environmental Cost Analysis Methodology (ref 19) presented in section 5 of this manual. The final selection of BMP(s) should be based on the relative performance capabilities of the BMPs at the specific sites and the overall economic benefit to range operations.

TABLE 3-2. BMP TRAINING AREA SUITABILITY MATRIX

	Lead Migration Prevention																									Pollution Prevention		
	Operational Changes					Vegetative Solutions						Storm water Management									Berm Design and Structural Enhancements		Geosynthetic Materials	Soil Amendments		Green Ammunition	Bullet Traps	Lead Removal
FCC No. Range Type	Firing Lane Use Management	Minimize/Eliminate Firing into Water Resources	Vegetative Cover Sustainment	Improved Range Maintenance Practices	Existing BMP Inspection and Maintenance	Vegetative Cover Establishment and Sustainment	Aerial Seeding of Inaccessible Areas	Grassed Channels/Swales	Grass Filter Strips	Riparian Buffer Zones	Erosion Control Mats and Mulches	Land Shaping	Diversion Channels and Dikes	Check Dams	Channel Stabilization	Turnouts and Aprons	Sediment Barriers	Dry Detention ponds	Sand Filters	Dust Control	Berm Design	Berm Structural Enhancements		Lime Amendments	Phosphate Amendments			
FCC 17730 Impact Area (Dudded)	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
FCC 17731 Impact Area (Nondudded)	-	X	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	X	X	X	-	X
FCC 17801 Rifle/Machinegun Range	X	X	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
FCC 17803 Automated Field Fire Range	-	X	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	X	X	X	-	X
FCC 17805 Automated Record Fire Range	-	X	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	X	X	X	-	X
FCC 17806 Modified Record Fire Range	-	X	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	X	X	X	-	X
FCC 17809 Qualification Training Range	-	X	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	X	X	X	-	X
FCC 17812 Automated Sniper Field Fire Range	-	X	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	X	X	X	-	X
FCC 17822 Automated Combat Pistol/Military Police Firearms Qualification Course	-	X	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	X	X	-	-	X
FCC 17829 Heavy Sniper Range	-	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	X	X	-	-	X
FCC 17833 Multipurpose Machinegun Range	-	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	X	X	-	-	X
FCC 17858 Scout/Reconnaissance Gunnery Complex (SCOUT/RECCE)	-	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	X	X	-	-	-

See legend and note at end of table.

TABLE 3-2 (CONT'D)

FCC No. Range Type	Lead Migration Prevention																									Pollution Prevention		Lead Removal
	Operational Changes					Vegetative Solutions						Storm water Management									Berm Design and Structural Enhancements		Geosynthetic Materials	Soil Amendments		Green Ammunition	Bullet Traps	
	Firing Lane Use Management	Minimize/Eliminate Firing into Water Resources	Vegetative Cover Sustainment	Improved Range Maintenance Practices	Existing BMP Inspection and Maintenance	Vegetative Cover Establishment and Sustainment	Aerial Seeding of Inaccessible Areas	Grassed Channels/Swales	Grass Filter Strips	Riparian Buffer Zones	Erosion Control Mats and Mulches	Land Shaping	Diversion Channels and Dikes	Check Dams	Channel Stabilization	Turnouts and Aprons	Sediment Barriers	Dry Detention ponds	Sand Filters	Dust Control	Berm Design	Berm Structural Enhancements		Lime Amendments	Phosphate Amendments			
FCC 17859 Digital Multipurpose Training Range	-	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	X	X	-	-	-
FCC 17860 Digital Multipurpose Range Complex	-	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	X	X	-	-	-
FCC 17865 Multipurpose Training Range	-	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	X	X	-	-	-
FCC 17867 Multipurpose Range Complex	-	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	X	X	-	-	-
FCC 17870 Battle Area Complex	-	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	X	X	-	-	-
FCC 17879 Live Fire Exercise Shoot House	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-
FCC 17891 Infiltration Course	-	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	-	-	X	X	-	X	X	X	-	-	X
FCC 17892 Fire and Movement Range	-	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	X	X	-	-	-
FCC 17893 Squad Defense Range	-	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	X	X	-	-	-
FCC 17895 Infantry Squad Battle Course	-	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	X	X	-	-	-
FCC 17897 Infantry Platoon Battle Course	-	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	X	X	-	-	-

FCC = Facility Category Code.
RECCE = Reconnaissance.

Note: X indicates that the BMP method is generally applicable to the range type.

TABLE 3-3. METALS TRANSPORT MECHANISM SUITABILITY MATRIX

BMP Category/Group	BMP List	Storm water Runoff Transport: Flow Rate Control	Storm water Runoff Transport: Volume Reduction	Storm water Runoff Transport: Erosion Control	Storm water Runoff Transport: TSS Reduction	Storm water Runoff Transport: Metals Reduction (Dissolved)	Surface Water Transport	Groundwater Transport	Aerial Transport
Lead migration prevention Operational changes	Firing lane use management	-	-	X	X	-	-	-	X
	Minimize/eliminate firing into water resources	-	-	-	-	-	X	-	-
	Vegetative cover sustainment	X	-	X	X	-	-	-	X
	Improved range maintenance practices	X	-	X	X	-	-	-	X
	Existing BMP inspection and maintenance	X	X	X	X	-	-	-	X
Vegetative solutions	Vegetative cover establishment and sustainment	X	-	X	X	-	-	-	X
	Aerial seeding of inaccessible areas	X	-	X	X	-	-	-	X
	Grassed channels/swale	X	X	X	X	-	-	-	X
	Grass filter strips	X	X	X	X	-	-	-	X
	Riparian buffer zones	X	X	X	X	-	X	-	X
	Erosion control mats and mulches	X	-	X	X	-	-	-	X
Storm water management	Land shaping	X	X	X	X	-	-	-	-
	Diversion channels and dams	X	X	X	X	-	-	-	-
	Check dams	X	-	X	X	-	-	-	-
	Channel stabilization	X	-	X	X	-	-	-	-
	Turnouts and aprons	X	-	X	X	-	-	-	-
	Sediment barriers	X	-	X	X	-	-	-	-
	Dry detention ponds	X	-	X	X	-	-	-	-
	Sand filters	-	-	-	X	X	-	-	-
	Dust control	-	-	-	-	-	-	-	X
Berm design and structural enhancements	Berm design	X	-	X	X	-	-	-	-
	Berm structural enhancements	X	X	X	X	X	-	X	X
Geosynthetic materials		-	-	-	-	-	-	X	-
Soil amendments	Lime amendments	-	-	-	-	X	-	X	-
	Phosphate amendments	-	-	-	-	X	-	X	-
Pollution prevention	Green ammunition	-	-	-	-	X	X	X	X
	Bullet traps	-	-	-	-	X	X	X	X
Lead removal		-	-	-	-	X	-	X	X

Note: X indicates that the BMP method is generally applicable to the transport mechanism.

TABLE 3-4. SITE SUITABILITY MATRIX SCREEN

Step 2 BMP List	Site-Specific Physical Parameters (Examples)							BMP Ranking (Total Number of √ marks)
	Soil Type	Depth to Groundwater	Distance to Surface Water	Dispersion of Rounds	Size of Drainage Area	Condition of Rounds	Backstop Berm	

How to use this table: If the BMP method can be implemented and be effective with respect to a specific site characteristic, then place a check (√)in the appropriate column for that parameter. If the site characteristic will limit the implementation or effectiveness of the BMP method, then place an (X) in the appropriate column for that parameter. The BMP methods can then be ranked based on their ability to be effectively implemented with respect to the site parameters.

3.2 Lead Migration Prevention

The prevention of lead migration from the range impact area is typically the least expensive and easiest to implement of the actions that may be taken to manage lead issues on active small arms ranges. The selection of the appropriate lead migration prevention method is the key to successful lead management on a range or group of ranges. This is because each firing range, or group of ranges, is unique in terms of lead concentration, climate, soils, physical and chemical properties, and topography. A plan for controlling lead migration must be designed on the basis of these site characteristics. Typically, these plans include designs to control storm water runoff, which is the predominant transport mechanism for lead. BMP methods for lead migration prevention are discussed below.

3.2.1 Operational Methods

Operational methods for range improvement are minor to moderate changes in the way a range is used or maintained in an effort to reduce munitions constituent transport from the range areas. In particular, concerns from lead residues and suspended solids (from soil erosion) leaving ranges or range areas may be decreased or eliminated through relatively simple changes to range management. These changes are intended to have no impact on training mission and can be implemented with little or no additional cost to the installation. The following operational methods will be discussed:

Range Use Practices - Range use focuses on simple changes in range use or how training is conducted that can decrease or eliminate potential environmental concerns. Potential changes to range use practices are as follows:

- Evenly distribute/stagger firing lane use on a range.
- Minimize or eliminate firing into bodies of water or wetlands.

Range Maintenance Practices - Range maintenance focuses on simple and easily implemented changes to common range maintenance practices that can decrease environmental concerns from small arms ranges. In addition, existing storm water management methods installed in the range areas should be included in a routine inspection and maintenance program to ensure continued effectiveness. Potential changes to range maintenance practices are as follows:

- sustain the vegetative cover on and around the range.
- improve impact berm maintenance and repair practices.
- implement an inspection and maintenance program for existing BMPs.

On the following pages, each of these BMP methods is discussed individually.

Firing Lane Use Management

Description: Typically, when training is conducted on 25-meter ranges, the troops are dispersed from the center lanes of the range (in front of the control tower) outward toward the end lanes. As a result, the firing lanes at the center of a range receive more use, and the corresponding wear on the berm is higher on the center lanes than on the lanes at each end of the range. This high-density use of the center lanes results in the potential for erosion to rapidly develop and requires frequent maintenance to maintain the stability of this section of the berm. Staggering the lane use to evenly distribute firing among all lanes should promote an even distribution of wear across the length of the berm.

Benefit: The even distribution of firing on all of the lanes of a 25-meter range may slow the development of unstable, highly erodable bullet pockets on the berm. The firing distribution will minimize the effects of the rounds impacting and disturbing vegetation around the bullet pocket areas. Minimizing vegetation disturbance on the berm may improve the survivability of the vegetation, which will in turn serve to control erosion from the disturbed bullet pockets that form across the face of the berm. This, coupled with the even wear on the berm, may reduce the frequency of maintenance required on the berm.

Applicability: Distribution of firing on the range primarily benefits 25-meter ranges ((Facility Use Category Code (FCC) 17801)) that use earthen berms as a backstop behind the fixed targets.

Limitations: The benefit of dispersing small arms firing over the length of the range will not be achieved if the berm has no vegetation established on it. In addition, if the berm slope is too steep, then the berm will erode quickly regardless of the distribution of firing. The recommended slope for an impact berm is 2:1 (horizontal to vertical ratio). In addition, the wider dispersion of the troops may require additional personnel to monitor the safe handling and use of the weaponry. This is primarily an issue on basic training ranges.

Implementation Guidance: No modifications or record keeping is required to implement this BMP. Dispersion of troops can be based on visual observation of berm wear (i.e., place troops on lanes that exhibit the least berm wear).

Maintenance Requirements: No additional maintenance is required. If successful, distribution of the firing should reduce the frequency of berm maintenance.

Cost Elements: No additional implementation or maintenance costs are associated with this BMP.

Minimize or Eliminate Firing into Water Resources

Description: Firing into bodies of water or wetlands increases the potential for ecological risk to lead exposure and increases the risk for lead migration; it should be avoided if possible. The use of ranges that fire into surface water resources should be minimized by shifting as much training as possible to other ranges on post where surface water resources are not impacted. Possible alternatives are to reorient the range to change the direction of fire away from the surface water resource or to incorporate a means of containing the rounds on the range (i.e., berm or bullet trap).

Benefit: The direct deposit of lead into surface water resources is limited, thus minimizing the potential for human health or environmental effects resulting from training range use.

Applicability: This range use practice has limited applicability. Most installations do not have the option to shift training to other ranges either because they lack redundant range types or the ranges have a common impact area that would result in the rounds potentially entering a common surface water resource.

Limitations: Training land and facility limitations are as described above. Options for moving training are to reorient the range, if possible, to direct rounds away from the surface water resource or to install a containment measure (berm or bullet trap) to capture and control the fired rounds. Reorienting the range would be very expensive and in most cases not practical because of surface danger zone (SDZ) considerations. Containment measures are discussed in Pollution Prevention, section 3.3 of this manual. The use of containment measures is limited by range design and training requirements. Containment measures are best suited for Zero and Known Distance ranges.

Implementation Guidance: No implementation actions are needed for shifting training other than identifying ranges whose use does not result in rounds being deposited in or adjacent to surface water resources. Range reorientation or installation of containment measures on ranges requires a significant engineering effort and financial obligation to execute. Current procedures should be followed to request a new range for range reorientation efforts. Containment measures are discussed in Pollution Prevention, section 3.3.

Maintenance Requirements: No maintenance requirements are associated with the training-shift portion of this BMP.

Cost Elements: No cost is associated with the training-shift portion of this BMP. Reorientation is equivalent to a new range cost. Containment measure costs are discussed in section 3.3.

Vegetative Cover Sustainment

Description: Vegetation is probably the single most cost efficient and effective means of controlling erosion and its subsequent soil and lead transport from small arms ranges. Some range maintenance practices do not support the maintenance of a healthy growth of grasses on the ranges. Loss of vegetation can greatly increase the likelihood of soil erosion and lead migration. If vegetation is present, it must be ensured that maintenance activities will sustain and promote its growth, especially on the berm and in storm water runoff pathways. Sustainable activities include annual (or semiannual) fertilization and lime addition based on a soil nutrient analysis and a mowing regime that allows tall vegetation on the berm and runoff pathways.

In addition to the sown vegetative cover on the range and berm, the natural vegetation (trees, vines, bushes, and grasses) around the range and impact areas should be protected from damage. Firing on the range may cause some damage to the natural vegetation, and this is expected and acceptable; however, care should be taken to prevent other activities (e.g., maintenance activities, troop movement, vehicular movement, prescribed burning) from damaging these areas, especially areas between the predominant impact areas on the range and nearby surface water resources. This vegetation acts as a natural buffer providing erosion control, storm water detention, and biofiltration.

Benefit: Mowing grass too short and too frequently may result in the development of shallow root zones. This is not healthy for the grass (i.e., the grass may be more susceptible to damage from foot or vehicle traffic, drought conditions, range fires, etc.) and limits its ability to keep erosion in check. Taller grasses provide a shield from the direct impact of rain drops on soils to prevent the start of the soil erosion process. Grasses allowed to grow taller also develop longer/deeper root systems below ground. Deeper more developed root systems help to hold more soil in place and generally increase the durability and the drought resistance of vegetation. Tall grasses also act as a filter for improving storm water runoff quality by slowing the storm water runoff and filtering out suspended solids before they leave the range.

Natural vegetation can provide water quality benefits of preventing off-range transport of sediments and lead, as described above. Natural vegetation offers several advantages to newly planted vegetation. Natural vegetation can usually process higher quantities of storm water runoff than newly seeded areas, does not require time to establish, has a higher filtering capacity than newly established vegetation because aboveground and root structures are typically denser, reduces storm water runoff by intercepting rainfall, promoting infiltration, and lowering the water table through transpiration, and usually requires less maintenance than newly planted vegetation (ref 20).

Applicability: Vegetative cover sustainment is applicable to all small arms ranges where both sown and natural vegetation exist and can be maintained. Areas where preserving vegetation can be particularly beneficial are ranges located in or near floodplains, wetlands, stream banks, steep slopes, and other areas where erosion controls would be difficult to establish, install, or maintain (ref 20).

Limitations: Vegetative cover sustainment may not apply to ranges in arid regions where establishing and maintaining thick, vegetative cover is extremely difficult or impossible. Research is currently being conducted to develop wear-tolerant grasses that may be able to be established in arid areas (see vegetation establishment BMP in paragraph 3.2.2 for more information on wear-tolerant species). In addition, vegetation on ranges may present a fire hazard where tracer rounds are fired during periods when the ranges are dry or under drought conditions.

Implementation Guidance:

Alter range mowing schedules and grass cutting heights. Mow ranges only frequently enough to maintain realistic and safe training conditions and target visibility, and to reduce the fire hazard if it is an issue. Mowing height guidelines for grass on ranges are as follows:

- **Between the firing point and the target:** Mow to the height required to prevent interference with the line of sight.

- **Behind the targets and on berms:** Allow the grass to grow as high as possible. Areas behind the targets do not affect line of sight and should be left to grow to a natural state. If mowing is needed, do not mow to a height of less than 4 inches.

Monitor and fertilize range soil. The fertility of the soil on a range will greatly affect the ability to maintain vegetation. Periodic sampling of soils for basic fertility properties such as pH, nitrogen, phosphorous, potassium (NPK) content, calcium-magnesium, iron, etc., should be performed to help manage vegetation. Soil sampling should be done at least on a yearly basis. The local or State Agricultural Extension Agency can usually provide information on how to collect the soil samples and will analyze the samples at a very low cost ($5 to $10 per sample). These agencies will analyze the soil samples for nutrient content and will recommend the amount of fertilizers or amendments that should be applied per unit area of range land. In general, a minimum of three samples per range should be collected from random locations in and around the general impact point of the rounds behind the targets. Areas that have particularly stressed or poor vegetation growth should be sampled and analyzed individually to look for the reason for the poor growth.

Allow range downtimes for vegetation recovery. If possible, ranges should be put on a usage-rotation schedule such that each range can be left idle for a growing season. This will allow vegetation to recover and reestablish itself from the wear caused by range use.

Preserve Natural vegetation. A map of the range should be prepared with the locations and boundaries of natural vegetation and buffer zones to be preserved. If possible, these areas should be marked to limit vehicular and troop activities that may damage the natural vegetation.

Prescribed burning erosion mitigation. If prescribed burning is used to remove vegetative fuel loads from small arms range areas, then temporary erosion control measures should be implemented to control sediment in storm water runoff. Erosion control measures should be maintained until vegetative cover has re-established. Do not burn grassed swales, vegetative filter strips, and riparian buffer zones to maintain their effectiveness in controlling sediment and metals transport from the range areas. If herbicide is applied prior to prescribed burning, then the area burned should be reseeded to accelerate the re-establishment of vegetation in the area.

Cost Elements: Reducing mowing frequency may result in a minor cost savings. Additional costs will be incurred for soil analyses ($5 to $10 per sample) and the purchase and application of fertilizers/soil nutrients if fertilization is not currently performed annually. The annual cost will depend on the number of ranges, the area requiring fertilization, and the amount of nutrients required to be added. See section 3.2 for costs associated with vegetation establishment.

Improved Range Maintenance Practices

Description: Some range maintenance practices or the lack of maintenance practices, may promote soil erosion and lead mobility on small arms ranges. Typical maintenance practices include:

- periodically scraping the face of the berms to smooth or fill in bullet pockets and remove vegetation
- grading the slope of the berms to approximately 1:1 (45^{o})
- prescribed burning of vegetation in and around small arms round impact points on the range and existing vegetative-based erosion control methods in the range area and adjacent to streams (i.e. grassed swales, grass filter strips, riparian buffer zones, etc.)

These practices disturb the entire surface of the berm and result in a slope and disturbed soil condition that promotes erosion. Berm maintenance activities should be changed from grading of the entire berm face to patching or refilling of bullet pockets or worn areas. In addition, the slope on the berm face should be maintained at a 2:1 maximum slope (approximately 25 to 30^{o}).

Benefit: A 2:1 slope will produce an inherently stable berm for most soil types on which it will be easier to establish and maintain vegetation. Berm repairs that focus on filling the impact points where concentrated round impacts have created holes in the berm will preserve any vegetation that exists on the berm and will not disturb (loosen) the soil around the bullet pocket areas. Avoiding damage or removal of the vegetation that has established on the berm, coupled with maintaining the appropriate berm slope, will greatly reduce soil erosion and munitions constituent transport from the berm.

Applicability: This BMP is applicable to any range type that uses backstop berms to capture and contain the rounds fired on the range. The design of berms to protect target mechanisms should continue to be constructed in accordance with the appropriate USACE design guidance for target installation.

Limitations: These maintenance methods can be applied to all ranges. Where severe erosion, lack of vegetation, or unstable berm designs currently exist, corrective action measures in accordance with the BMP methods presented in the vegetation establishment or berm design sections (para 3.2.2 and 3.2.4, respectively) of this manual must be implemented for the site-specific problems.

Implementation Guidance: No implementation actions over current maintenance practices are needed except that berm slopes should be maintained at a maximum 2:1 slope and maintenance activities should be restricted to the disturbed bullet pocket or wear areas only on the berm. If this berm slope or vegetation does not currently exist, then the BMP methods for establishing vegetation and berm modification should be implemented and followed with the maintenance guidance provided here.

Cost Elements: The cost elements required to conduct these maintenance activities do not differ significantly from current practices. The activities can easily be performed with installation or troop labor and equipment. Maintaining stable slopes will reduce the erosion and reduce the frequency of conducting maintenance on the berms. This may result in an overall maintenance cost savings.

Existing BMP Inspection and Maintenance

Description: Preventive maintenance should be conducted to monitor and repair existing storm water BMPs to maintain their effectiveness. This approach to storm water management seeks to prevent problems before they occur. Generally, inspection and maintenance of the installed storm water BMPs can be categorized as either expected routine maintenance or nonroutine (repair) maintenance.

Routine maintenance checks should be made on the BMPs to keep them in good working order. This is also an efficient way to reduce the need for repair maintenance and reduce the chance of polluting storm water runoff by finding and correcting problems before the next rain. Routine inspection should occur for all storm water and erosion and sediment control measures implemented in a range area. These implemented measures may include vegetated areas and swales, areas stabilized by geotextiles, check dams, silt fences, soil dikes, brush barriers, sediment traps or basins, wet or dry detention basins, etc. Nonroutine maintenance includes major repairs after a violent storm or extended rainfall, or replacement of existing storm water control measures (ref 21).

Benefit: The implementation of preventive maintenance practices will ensure that installed BMPs will continue to perform efficiently at minimal cost.

Applicability: All storm water BMPs should be inspected regularly for continued effectiveness and structural integrity.

Limitations: Routine maintenance materials and labor are usually readily available and can be obtained on short notice. Some of the more complicated structural BMPs may require items that may not be available to support emergency repairs. These BMPs may require the stockpiling of essential materials to support emergency repairs.

Implementation Guidance: The types and frequency of inspections and routine maintenance will vary depending on the type of storm water BMP installed. Suggested inspection and maintenance criteria for each type of BMP are included in the implementation guidance provided for each BMP in this manual. Refer to the appropriate BMP section for this guidance. When conducting any inspection, the inspector should document whether the BMP is performing correctly, any damage that has occurred since the last inspection, and what should be done to repair the BMP if damaged.

Cost Elements: Maintenance work on storm water BMPs is not usually complicated (e.g., mowing, sediment removal). As a result, most work can be easily contracted or performed by troop labor. However, some of the more sophisticated structural BMPs may require specialized maintenance training to maintain the system. The specific maintenance requirements and associated cost elements for each type of BMP are provided in this manual. Refer to the appropriate BMP section for this guidance.

3.2.2 Vegetative Solutions

Vegetative solutions provide an efficient and economical method of controlling sheet, rill, and raindrop impact erosion. Vegetation slows the storm water runoff and filters out suspended solids before they leave the range. The protective effect of the plant is enhanced by roots and rhizomes that hold the soil in place, improve the physical condition of the soil, and increase the rate of infiltration, further decreasing runoff. Vegetative cover is relatively inexpensive to achieve and tends to be self-healing. It is often the only practical, long-term solution for stabilization and erosion control on most disturbed sites. Plant selection, combined with soil management practices such as fertilization, liming, and addition of other soil amendments to increase soil fertility and improve soil characteristics, will increase the chance for a sustainable vegetative cover. Soil texture and nutrient content are key parameters for the successful establishment and maintenance of vegetation. The methods of establishing vegetation and some specific uses of vegetation on range areas include

Vegetation Cover Establishment and Sustainment - A vegetative cover provides excellent long-term erosion protection and sediment transport control. This BMP will review factors affecting the establishment and sustainment of vegetative cover and actions that can be taken to promote vegetation growth.

Vegetative Storm Water Management and Erosion Control Practices - Beyond the general establishment and sustainment of a vegetative cover, specific uses of vegetation have been identified that can be applied to small arms range areas

- aerial seeding of inaccessible impact areas
- grassed channels/swales
- grass filter strips
- riparian buffer zones
- erosion control mats and mulches

Each of these BMP methods is discussed individually below.

Vegetative Cover Establishment and Sustainment

Description: Establishing a vegetative cover is critical to storm water management. Maintaining a vegetative cover on the entire range (with special attention paid to backstops, impact areas, and runoff flow paths) is the best way to reduce off-range transport of lead and sediment.

Benefit: Vegetative covers can provide both dust control and a reduction in erosion on any small arms range area up to and including the area immediately surrounding the primary concentrated impact points on range, on the impact berms, or in the impact area. Vegetation should be the first BMP considered when addressing soil erosion or storm water or wind-driven lead transport issues. Perennial vegetative cover has been shown to remove between 50 and 100 percent of total suspended solids from storm water runoff with an average removal of 90 percent (ref 22). The vegetative cover minimizes the initiation of erosion by dissipating the energy of raindrop impacts. The use of rhizomic grasses can benefit slope stabilization because their deeper root systems are able to enhance soil stability. In addition, these rhizomic grasses have improved wear tolerance when trampled or disturbed because their deeper root systems allow quicker recovery from damage.

Applicability: Vegetative covers are applicable to any small arms range area up to and including the area immediately surrounding the primary concentrated impact points on the range, on the impact berms, or in the impact area.

Limitations: Vegetation may be difficult and slow to establish and maintain at some small arms ranges. The vegetation may be cut down or uprooted by shooting activities or trampled by Soldiers moving between firing stations and targets. Perennial seeding does not immediately stabilize erosive soils. As a result, temporary erosion and sediment control practices may need to be implemented to control erosion and sediment transport until the plants are established.

State and local environmental or natural resources agencies may have concerns about altering the physical soil characteristics from their natural conditions based on a desire to preserve the natural ecological system or for other reasons.

Careful selection and application of fertilizer is needed near surface water resources to prevent nutrient loading and possible eutrophication in the water.

Land-based broadcast or hydroseeding may not be viable options because of accessibility problems. Access may be limited because of the presence of unexploded ordnance (UXO) or rugged terrain. The aerial seeding BMP is a potential option in these cases.

Implementation Guidance: The two major factors affecting the establishment of a sustainable vegetative cover are soil management and plant selection. These factors and the actions that can be taken to promote vegetation growth are presented below.

Soil Management

The primary soil properties that affect the establishment and growth of vegetation are soil texture and soil nutrients. Soil texture is an expression of the relative amounts of sand, silt, and clay in a soil. Texture is a key property of soils that affects a wide variety of soil related phenomena, including drainage, erosion, plant ecology, and suitability for construction. The selection of the appropriate vegetation for the range area may be dependent upon or limited by soil texture.

Modifications to soil texture are possible but recommended only when the available vegetative options for the type of soil present will not provide protection from storm water erosion. Prior to considering soil texture modification, an evaluation of current soil characteristics and ability of the soil to sustain erosion-inhibiting vegetation should be performed. The local NRCS or agricultural extension service should be able to determine the soil texture and advise whether changes are required to establish erosion-inhibiting vegetation.

Nutrient addition and pH adjustment are often needed to establish or maintain vegetation on a range. The primary nutrients for vegetative growth are nitrogen, phosphorus, and potassium. In addition, soils that contain low organic matter content and inadequate microbial population will inhibit the ability to establish and maintain vegetative growth. Failure to apply needed nutrients may result in poor establishment or complete failure of a seeding effort. Soil samples must be analyzed to detect nutrient deficiencies. The application of fertilizer is only beneficial if the proper kinds and quantities are applied. The local NRCS or agricultural extension service can perform these analyses and determine the appropriate type and rate of nutrient application to address the soil deficiencies.

Generally, slow-release fertilizers work most effectively for seeding, vegetation planting, and maintenance activities. These fertilizers provide plant nutrients by either soil bacterial action or an osmotic process to release the nutrients. Fast release fertilizers make nutrients available for immediate use. These fertilizers are best adapted to maintenance operations rather than seeding or planting efforts. If applied before seeding, the nutrients can leach out of the soil before the seeds can germinate. Fast release fertilizers should not be used near surface water resources to prevent nutrient leaching or runoff to the water; only slow-release fertilizers should be used in these areas.

In addition to nutrients, soil pH adjustment is often needed to support range vegetation. The soil pH affects the ability of the plants to extract nutrients from the soil. When analyzing for soil nutrient content, the soil pH should also be determined. If the soil pH is too low (acidic), then some form of lime can be added to raise the pH to the appropriate range to support vegetation. If the soil pH is too high (alkaline), then organic matter (peat moss, sawdust, composted leaves, woodchips, etc.) or sulfur can be added to lower the pH. The local agricultural extension service can make recommendations for pH adjustment based on the soil analysis.

When possible, organic matter should be added to the soil. Organic matter (humus or compost) will bring the pH closer to neutral (if alkaline), improve the moisture holding capacity of the soil, and provide a source of slow-release plant nutrients. Some cost-effective organic soil amendments include manure, treated sewage sludge, and composted organic wastes.

Plant Selection and Establishment

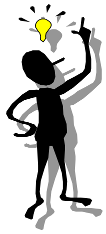
Plant selection should focus on the use of noninvasive species that are appropriate for the local climate. Plants that are hardy and able to withstand the environment should be chosen. A Web-based tool called VegSpec provides a decision support system that assists in the planning and design of vegetative establishment practices. VegSpec was developed cooperatively by the NRCS, the Forest and Rangeland Ecosystem Science Center of the Biological Resources Division of the USGS, and the Engineer Research and Development Center – Construction Engineering and Research Laboratory (ERDC-CERL) in Champaign, Illinois. VegSpec uses soil, plant, and climate data to select plant species that are site-specifically adapted and appropriate for controlling storm water runoff and erosion. The program uses the information to provide a selection of plants that can be used to resolve the specified problem. In addition to VegSpec, the Engineering Research and Development Center – Cold Regions Research and Engineering Laboratory (ERDC-CRREL) is also developing improved native grasses that provide better resilience to training land impacts. Two of the species already developed are western wheatgrass and Snake River wheatgrass, both of which showed promise as stabilizing species in tests conducted at the Yakima Training Center and Fort Carson. The two species were able to spread into damaged areas (ref 23). This self-spreading trait may result in reduced range downtime and lower seeding costs to maintain vegetation on ranges. Other resilient native species that may be available for future range use are being developed by ERDC-CRREL.

TIP:
The VegSpec program is online at: http://ironwood.itc.nrcs.usda.gov/Netdynamics/Vegspec/pages/HomeVegspec.htm.

Once the appropriate plants are selected and the required soil amendments have been determined, the site activities to establish the vegetative cover should be planned. Generally, this involves site preparation, planting, and erosion control. Site preparation, at a minimum, includes the following actions:

- Complete all grading, if necessary, to control storm water runoff.
- Install temporary erosion control and sediment trapping practices such as temporary diversion dikes, and silt fences.
- Amend the soil in accordance with NRCS or agricultural extension service recommendations to ensure soil nutrients and pH that support plant growth.
- If the soil is compacted, crusted, or hardened, loosen it by disking, raking, or harrowing.

Following site preparation, the seed should be uniformly distributed on the soil with a spreader or by hydroseeding. Application rates and methods should be based on the recommendations provided by the NRCS or agricultural extension service. After seed application, erosion control blankets should be installed, or the seeded areas should be mulched to minimize sheet flow erosion and to aid the retention of water until the plants are established. The BMP for erosion control mats and mulches may be referred to for guidance in selecting the appropriate temporary erosion control materials for the seeded site.



TIP:
Refer to the following SEDSPEC Web address for additional guidelines for establishing vegetative cover:
http://owww.cecer.army.mil/ll/sedspec/design/DisplayMeth.cfm?PKeyMethod=38&FROMUSE=13&PKEYPRACTICE=6 (ref 24).

Maintenance Requirements: Soils should be tested annually in the spring or fall to determine nutrient addition requirements. Particular attention should be paid to areas where symptomatic color or lack of plant growth suggests a soil nutrient deficiency. Fertilizers should be applied in the spring or fall. In addition, any erosion should be repaired by filling, seeding, and fertilizing the eroded areas. Seeded areas should be inspected for failure, and necessary repairs should be made and reseeding should be accomplished as soon as possible.

If range fires occur, actions should be taken to control erosion and facilitate the re-establishment of vegetation in the burned areas to control metal constituent transport and sediment movement. If prescribed burning is used to remove vegetative fuel loads from small arms range areas, then temporary erosion control measures should be implemented to control sediment in storm water runoff. Erosion control measures should be maintained until a vegetative cover has reestablished. Do not burn grassed swales, vegetative filter strips, and riparian buffer zones to maintain their effectiveness in controlling sediment and metals transport from the range areas. If herbicide is applied prior to prescribed burning, then the area burned should be reseeded to accelerate the re-establishment of vegetation in the area. Recovery from both uncontrolled and controlled range fires should be included in operation and maintenance (O&M) budgets to ensure range sustainment activities can be maintained.

Cost Elements: The cost elements specific to vegetation establishment and sustainment will be discussed in this section. The cost elements associated with any site grading or sediment trapping, if necessary to support vegetation establishment, are identified in the applicable storm water management or berm design BMPs in paragraphs 3.2.3 or 3.2.4. In addition, temporary erosion control costs should be based on the cost elements identified in the Erosion Control Mats and Mulches BMP later in this section.

The cost elements specific to soil amendment and seeding activities are presented in Table 3-5. The cost of each element will vary with the type and amount of required amendments and seed. Typical equipment requirements will consist of a tractor with a drop spreader and disks for amendment/seed application. Hydroseeding equipment may also be needed to seed slopes inaccessible by a tractor.

TABLE 3-5. VEGETATION ESTABLISHMENT AND MAINTENANCE COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	Annual Operation and Maintenance		
Soil analysis	Soil analysis	Document maintenance	Range downtime
Seed selection	Soil amendment (and seed, if needed) material cost	Environmental management plan development and maintenance	
Soil amendment and seed material cost	Soil amendment and seed application labor cost		
Soil amendment and seed application and seed labor cost	Soil amendment and seed application equipment cost		

Aerial Seeding of Inaccessible Impact Areas

Description: Aerial seeding is the application of plant seed by aircraft. The procedure is carried out as an alternative to broadcasting and hydroseeding to increase the vegetative cover on areas that are not readily accessible. It is typically done where erosion hazard is high and native plants have been unable to establish in the area.

Benefit: Aerial seeding provides a means of establishing soil-stabilizing plant growth in range areas that are inaccessible because of the presence of either UXO or rugged terrain. It can generally be performed quickly and at a fairly low cost. The establishment of a vegetative cover in these barren areas controls soil erosion and builds root mass and organic matter in the soil, which makes it more hospitable for native species to take root. Eventually, a self-sustainable cover of native species may replace the sown vegetative cover.

Applicability: Aerial seeding is applicable to any small arms range area up to and including the area immediately surrounding the primary concentrated impact points in the impact area. It is generally the seeding method of last resort when access issues (UXO or rugged terrain) prevent the use of land-based broadcasting and hydroseeding methods.

Limitations: There are many challenges to the establishment of vegetative cover with aerial seeding. Successful plant stand establishment is weather-dependent. Seeding must be performed when the surface soil is moist or prior to an anticipated rainfall to improve the chances of germination. Timing of the seeding operation to coincide with the appropriate weather events may be difficult to coordinate with the training schedule. Generally, low-flying helicopters or planes are not allowed over the impact area while the ranges are in use. In addition, high wind conditions can impact seed distribution. More seed is usually needed to ensure good coverage of the area, which increases the material cost of the seeding operation. Successful stand establishment can also be inhibited by compacted soils and water ponded on the surface, resulting in low survival rates (ref 25).

Implementation Guidance: The major factors that affect good aerial seeded cover establishment are soil surface conditions, seed selection, seeding rates, and seeding time (ref 25). These factors are discussed below, and general guidance for successful aerial seeding operations is provided.

Soil surface conditions will have a major effect on plant stand establishment. If the soil is compacted, then the seeds will lie on the surface instead of penetrating into the soil on impact. The seed on the soil surface may not survive because the soil surface may be too dry to support germination or cold weather may damage developing seedlings and exposed roots. This inability to actively incorporate the seeds into the soil makes aerial seed establishment a high risk compared to normal, land-based seeding methods.

Seed selection can affect the ease of application and long-term survivability, and it may impact the ability of native species to regenerate in the area of concern. Larger, heavier seeds may enhance plant establishment because of their ability to penetrate into the soil upon impact.

Lighter seeds are less likely to penetrate the soil surface. They may also drift in the wind during aerial broadcasting, resulting in an uneven surface distribution in the range area of concern or drifting to other areas. As with vegetative cover plant selection, VegSpec should be used to identify potential plant types, which should be reviewed with the NRCS or the local agricultural extension service to make a final selection of seed to support erosion control and long-term native species development. These organizations should be able to provide guidance on aerial application rates and methods for the site conditions to improve the chances for plant establishment.

To maximize the chance for successful plant establishment using aerial seeding, the following actions are recommended:

- Do not attempt aerial seeding without a well-developed plan.

- Gather as much information as possible on the soil conditions in the range impact area. Depending upon safety issues, this may be limited to over flight observations and NRCS soil survey report information. Identify the specific areas to be seeded and determine the size of the areas.

- Gather meteorological data (monthly average and peak wind velocity, precipitation amounts, and temperature range) for the general range area.

- Consult with NRCS and the local agricultural extension service on the selection of the seed mix, soil amendment requirements, application rates, and application timing.

- Establish a seeding contract with a company that has a pilot experienced in the application of seed and the equipment necessary to spread the selected seed and soil amendments at the desired application rates. The contract should specify the conditions under which the seed can be applied (e.g., maximum wind velocity, precipitation, surface runoff conditions).

- Obtain any permits or waivers to allow over flight of the training areas, if necessary. At minimum, confirm that the flight schedule and flight path have been approved by the Range Manager. This must be done to ensure the pilot's safety and to prevent any interruption in training.

Maintenance Requirements: Annual fertilization and overseeding, if necessary, should be performed to maintain the vegetative cover.

Cost Elements: The cost for aerial seeding will vary based on the type and amount of soil amendments and seed required and the local availability of a pilot with the experience and equipment to support the operation. In addition, the concerns raised in the implementation guidance section identify site factors that may result in increased costs to successfully establish vegetation in inaccessible areas. Typical cost elements associated with planning, applying, and maintaining vegetation using aerial seeding are presented in Table 3-6.

TABLE 3-6. AERIAL SEEDING COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Soil analysis	Soil analysis	Document maintenance	Range downtime
Seed selection	Planning	Environmental management plan development and maintenance	
Planning	Contracting for aerial application		
Contracting for aerial application	Soil amendment and seed material cost		
Soil amendment and seed material cost	Labor to support amendment/seed application		
Labor to support amendment/seed application			

Grassed Channels/Swales

Description: Grass-lined swales are the most common form of channel protection. They offer a low-cost and effective method of controlling erosion within the swale and sediment removal from the runoff. As storm water runoff flows through the swale, the vegetation filters the flow. The swale may also be designed to promote filtration through a subsoil matrix or infiltration into the underlying soil, if site conditions permit. Variations of the grass-lined swale include the grassed channel, dry swale, and wet swale. The design features and methods of runoff quality management are all improvements over the traditional drainage ditch (ref 26). A grass-lined swale is shown in Figure 3-1 (ref 27).

Figure 3-1. Grass-lined swale. (Source: ERDC-CERL, 2004)

Benefit: A properly designed grass-lined swale can effectively remove suspended solids and trace metals. Depending on the site conditions, the swale can be designed to accomplish this through one or more of the following mechanisms: filtering by the vegetation, infiltration into the soil, or filtering through a subsurface matrix. The swale designs can be augmented by other storm water management methods, such as check dams, and grassed filter strips, making the grassed swale a good foundation method for storm water management and sediment control.

Applicability: Grass-lined swales are particularly effective at the base of impact berms located behind targets, as are often found on 25-meter ranges (FCC 17801). They may be effectively applied to collect and transport runoff from known concentrated impact points within the impact area (if nondudded) to other storm water management features, such as detention ponds or to areas where the runoff can be released without erosion or sedimentation damage. Discharges from swales should be transitioned to areas where sheet flow and infiltration can occur. Discharges to open water sources should be avoided whenever possible. Grass-lined swales may also be applied on ranges to collect and transport runoff from concentrated impact points in front of or behind automated targets on ranges such as the Automated Field Fire (AFF) (FCC 17803), Automated Record Fire (ARF) (FCC 17805), and Modified Record Fire (MRF) (FCC 17806). Grass-lined swales may be incorporated into flow diversion management methods that may be used on these ranges if overland flow occurs in sufficient volumes and flow rates are enough to mobilize sediments from their concentrated impact points.

Limitations: The use of grass-lined swales may depend on site-specific conditions such as the size of the area being drained, the slope of the area, the permeability of the soil layers, and the ability to establish and maintain a thick, healthy vegetative cover within the swale. If the area being drained generates a large volume of water that the swale must manage, then a swale large enough to manage the water volume may not be feasible. Coupled with the water volume issue is the slope of the swale. If the slope of the swale exceeds 4 percent (1 to 2 percent is recommended), then the water velocity may be too great, resulting in erosion within the swale. Soil permeability may limit infiltration, resulting in standing water that may create mosquito or odor problems on the range. In addition, if a dense vegetative cover cannot be maintained within the swale, then the filtering ability of the swale will be greatly diminished (ref 28).

The runoff water quality benefits of the different swale designs have not been fully documented. The limited data collected to date suggest high removal rates for suspended solids and metals ((median removal of 81 and 67 percent (ref 28), respectively)). It is difficult to distinguish differences in removal effectiveness between the different basic swale designs. Site-specific conditions may have a significant impact on the relative performance of the different designs and must be carefully evaluated by an experienced engineer. In addition, long-term performance is not known. The effects of sedimentation on performance and metal removal rates over time need further study to fully quantify long-term performance and maintenance requirements (ref 28).

Implementation Guidance: Before drainage improvements are made, the installation environmental office should be consulted to determine local permit and construction guidelines. Grass-lined swales applied in range areas should not be installed without a design based on an engineering survey and layout. The basic design considerations for grass-lined swales are similar to those for riprap-lined swales and diversion channels. The following design considerations apply to all three types of grass-lined swales: the grass channel, the dry swale, and the wet swale. Specific design requirements for each swale design will follow. The design requirements identified here are based on the grass-lined swale guidance provided by the USEPA (see ref 26 and 28 for additional guidance on swale designs and applications).

- The swale design capacity should be based on a 10-year design storm (minimum) (see design storm guidance provided in the storm water management section of this manual, paragraph 3.2.3.

- The peak flow that the grass-lined swale will be expected to manage must be identified to design the channel size and shape. The maximum flow rate of a grass-lined swale should be less than 4 feet per second. Erosion may occur at higher flow rates, requiring hardened liners such as riprap.

- Wide, shallow swales with gentle side slopes of 3:1 to 4:1 are recommended. Trapezoidal or parabolic-shaped swales are preferred because they produce the slowest runoff velocities within the swale. Typically, the flat bottom of the swale should be between 2 and 8 feet. The minimum width ensures a minimum filtering surface area, and the maximum width prevents the formation of channels within the swale bottom.

- No sharp curves or significant changes should be made to the slope. The preferred slope is 1 to 2 percent with a maximum slope of 4 percent.

- Plant selection for the swale should provide a dense vegetative cover to filter the water. The swale design and plant selection should be such that the depth of the water flowing through the swale does not exceed the height of the vegetative cover.

- Swales should generally provide drainage for areas of less than 5 acres. Larger areas may produce flow volumes and velocities that are too large to permit the desired water quality management benefits of the grass-lined swale.

Grassed Channels

The grassed channel (fig. 3-2) is the simplest and least costly of the swale designs (ref 27). It is basically a broad, shallow ditch with a grass lining. The primary water quality management benefit is derived from the lowering of the flow velocity and filtration of the runoff by the grass. In most cases, this design should be sufficient to lower suspended solids and total lead levels in the runoff from the range areas to acceptable levels. No additional design criteria beyond the basic criteria presented above is required to implement grassed channels on a range.

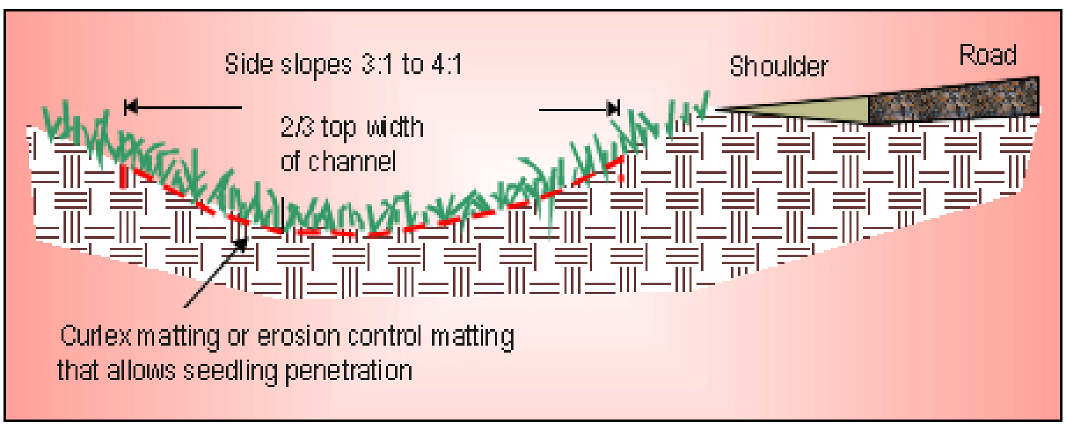


Figure 3-2. Grassed channel. (Source: ERDC-CERL, 2004)

Dry Swales

The dry swale incorporates a filtering media with a French drain type design into the bottom of the swale (fig. 3-3). The outward appearance is the same as that for the grassed channel. In this design, the soil in the flat bottom of the swale is replaced with a sand/soil mix that meets a minimum permeability requirement of 0.5 inches per hour (ref 26). Underneath this sand/soil mix is a gravel layer that encases a perforated pipe. The storm water runoff in the swale filters through the sand/soil mix and into the drainage pipe. This pipe may discharge the water to another storm water management feature such as a detention pond or to areas where the runoff can be released without erosion or sedimentation damage. The suspended sediments and trace particulate metals are captured in the sand/soil mix. If dissolved-phase lead is a concern, then an alkaline material (i.e., limestone) or a reactive material (e.g., phosphate, sulfide, carbonate) may be incorporated into the sand/soil mix to facilitate the precipitation of the lead ions by means of either a pH shift in the filtering media or by a reaction with the lead ions to form relatively stable lead species. The thickness of the sand/soil filtering media, as well as the amount of alkaline or reactive material to mix into the filtering media, will depend on the total and dissolved lead concentrations in the runoff water, the available infiltration area of the swale, and the volume and flow rate of the runoff being managed.

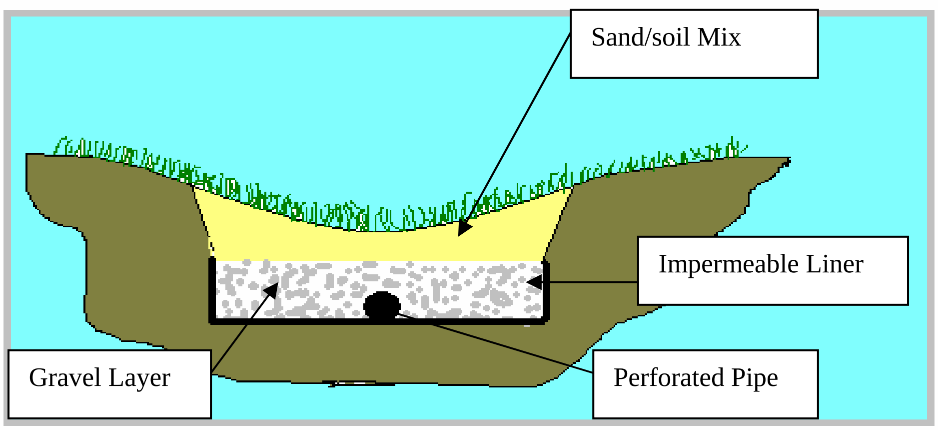


Figure 3-3. Dry swale.

The long-term performance of the dry swale is not known. Over time, the buildup of sediment and particulate metals in the sand/soil mix may result in plugging the filtering media, rendering it ineffective. Alkaline or reactive materials incorporated into the sand/soil mix may deplete over time and require replacement. In addition, mixing in too much of the alkaline or reactive material may create adverse water quality issues such as elevated discharge water pH or elevated nutrient content. Care must be taken in the selection of the appropriate type of reactive materials because some forms of the material may go into solution faster than other forms. This too could result in elevated nutrient levels in the discharge water. Issues with the use of reactive materials to control dissolved-phase lead are discussed in the soil amendments section (para 3.2.6) of this manual. The concerns expressed there also apply to the amendment's application in the dry swale sand/soil filter media.

Wet Swales

Wet swales intersect the shallow groundwater and act as wetland cells. They incorporate a permanent pool and wetland vegetation to provide storm water runoff quality management. These swale designs would be highly effective in managing the storm water quality, but they provide a direct transport path for the lead to the shallow groundwater (ref 26). Typically, this should be avoided. Furthermore, creating a wetland or pond on the range runs counter to previous guidance to avoid impacting such water sources. As a result, wet swales should not be used in range applications as a storm water runoff management method.

Maintenance Requirements: The maintenance objectives of grass-lined swales are to maintain the efficiency of the swale system in sediment and metals removal. Maintenance activities that are common to all swale designs include:

- Periodic mowing to maintain a healthy grass cover. The grass should never be cut shorter than the design flow depth of the swale.
- Annual fertilization based on soil test results.
- Removal of accumulated sediments to prevent a damming effect from sandbar formation and to avoid resuspension of the sediments within the swale. At a minimum, sediments should be removed prior to sediment accumulations reaching 25 percent of the original design volume of the swale.
- Inspection for and correction of erosion problems within the swale annually and after major storm events. Removal of trash and debris during inspections.
- If prescribed burning is used to reduce vegetation fuel loads in range areas, do not burn the vegetation in the grassed swales.

In addition to these maintenance requirements, dry swales should be inspected for indications of plugging of the sand/soil filter media. Ponding of water within the swale is an indication of low infiltration rates and filter media plugging. If infiltration has slowed, the sediment that has collected on the surface and the top 1 to 2 inches of the sand/soil mix should be removed. The remaining sand/soil mix should be rototilled, and the filter media should be replenished with new sand/soil. Next, seeding should be done to establish a new grass cover over the area.

If alkaline or reactive amendments have been added to the dry swale filter media, then the discharge from the outlet pipe should be tested annually to ensure that total and dissolved lead concentrations continue to meet design specifications. The need for amendment addition should be determined based on these results.

Cost Elements: The successful use of channels/swales to control erosion and lead transport on small arms ranges requires adequate storm water management designed by an experienced engineer. The typical cost elements associated with this BMP are presented in Table 3-7. The major factors that can affect the performance and cost of this BMP are improper design for runoff conditions and improper maintenance of the channel/swale vegetation.

TABLE 3-7. GRASSED CHANNEL/SWALE COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Surveying	Labor to inspect and maintain the channel/swale	Document maintenance	BMP overhead
Channel/swale design	Soil amendment/seed materials	Environmental management plan development and maintenance	Range downtime
Planning	Mowing and spreading equipment rental		
Contracting			
Construction permitting			
NEPA documentation			
Labor for channel/swale installation			
Material for channel/swale installation			
Equipment rental			

NEPA = National Environmental Policy Act.

Grass Filter Strips

Description: Filter strips are strips or areas of vegetation placed between a disturbed area and a potentially environmentally sensitive area (fig. 3-4; ref 29). This practice is used to reduce sediment, particulate organic matter, sediment-adsorbed pollutants, and soluble pollutants in surface runoff. In range applications, the filter strips can be used to slow sheet flow runoff, trap sediment and metals, and enhance infiltration within the buffer. If properly installed and maintained, filter strips have the capacity to remove 70 percent or more of sediment (ref 30).

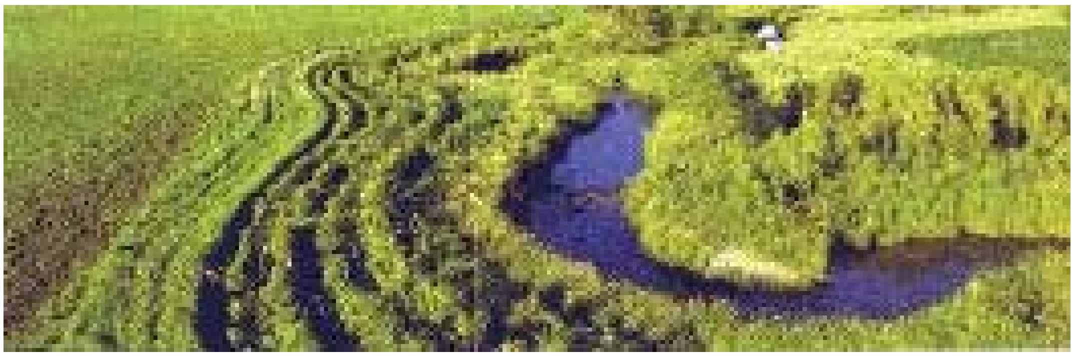


Figure 3-4. Grass filter strip. (Source: USEPA, 2004)

Benefit: Grass filter strips can effectively remove suspended solids and trace metals from overland sheet flow. They also promote infiltration of runoff water into the soil. Grass filter strips can augment the design of other storm water management methods (e.g., diversions, swales) by providing an additional sediment control mechanism at the inlet and outlets of these structures.

Applicability: Grass filter strips can be widely used in range applications. The strips may be applied at the inlet and outlets of grass-lined swales and storm water management structures, such as diversions and detention ponds to manage sediment loads in the runoff. They can be established in sheet flow drainage paths between concentrated small arms round impact points and nearby water resources. The strips can be located at the base of impact berms and in flow paths away from the berms, if sheet flow is maintained in these areas. Proper grading must be established and maintained for filter strips to be applied at the base of impact berms on ranges such as the 25-meter ranges (FCC 17801). They may be effectively applied to filter sheet flow runoff from known concentrated impact points within the impact area (if nondudded). Grass filter strips may also be applied on ranges to filter sheet flow runoff from concentrated impact points in front of or behind automated targets on ranges such as the AFF (FCC 17803), ARF (FCC 17805), and MRF (FCC 17806) as long as the grass height does not interfere with the line-of-site with the targets on the range.

Limitations: For the filter strips to perform effectively, sheet flow must be maintained through the strip. This may be difficult, especially on steep grades where water may concentrate and short circuit the filter strip, thus receiving little or no filtering benefit. In addition, the required width of the filter strip will vary with the flow rate of the runoff. This may present a problem in some areas where space limitations will not allow the installation of a properly designed filter strip.

Implementation Guidance: Prior to making drainage improvements, consult with the installation's environmental office to determine local permit and construction guidelines. Grass filter strips in range areas should not be installed without a design based on an engineering survey and layout, especially when used in conjunction with other storm water management practices. The basic design considerations for grass filter strips are as follows:

- As storm water flows over long lengths of the ground, the flow changes from a sheet flow to a concentrated flow. This concentrated flow may move too quickly through a filter strip for the sediment and metals load to be effectively managed. When designing and locating filter strips, the length of the drainage area over which sheet flow travels to reach the filter strip must be less than 150 feet (ref 30) to minimize flow concentration prior to reaching the filter strip.

- Filter strips should be established on low slopes (2 to 6 percent) (ref 30). Steeper slopes result in the formation of concentrated flow. Slopes lower than 2 percent may result in ponded water within the filter strip.

- Soils should be amended as necessary to support plant growth (see BMP for establishing vegetative cover for soil amendment and seeding guidance).

- The filter strip should be at least 25 feet wide (ref 30) to manage the sediment and metal load in the storm water runoff.

- The plant selection should focus on vegetation that can withstand the flow velocity through the filter strip and survive both wet and dry cycles. Generally, the plants selected for the rest of the range will be sufficient for the filter strip.

The design requirements identified here are based on the grass filter strip guidance provided by the USEPA (see ref 30 for additional guidance on filter strip design and application).

Maintenance Requirements: Generally, grass filter strips will require the same maintenance as vegetative cover. Soils should be tested each spring to determine nutrient addition requirements. Particular attention should be paid to areas where symptomatic color or lack of plant growth suggests a soil deficiency. Fertilizers should be applied in the spring. When mowing is required, a 4- to 6-inch grass height should be maintained. Annually and after major storm events, the filter strips should be inspected for signs of erosion (rill and gully formation). If erosion is occurring, the eroding areas should be repaired and reseeded. In addition, sediment that may have built up around or within the filter strip should be removed. If prescribed burning is used to reduce vegetation fuel loads in range areas, do not burn the vegetation in the grass filter strips.

Cost Elements: The successful use of grass filter strips to remove sediment and lead in small arms range runoff water requires storm water management designs by an experienced engineer. The typical cost elements associated with this BMP are presented in Table 3-8. The major factors that can affect the performance and cost of this BMP are improper design for runoff conditions and improper maintenance of the filter strip vegetation.

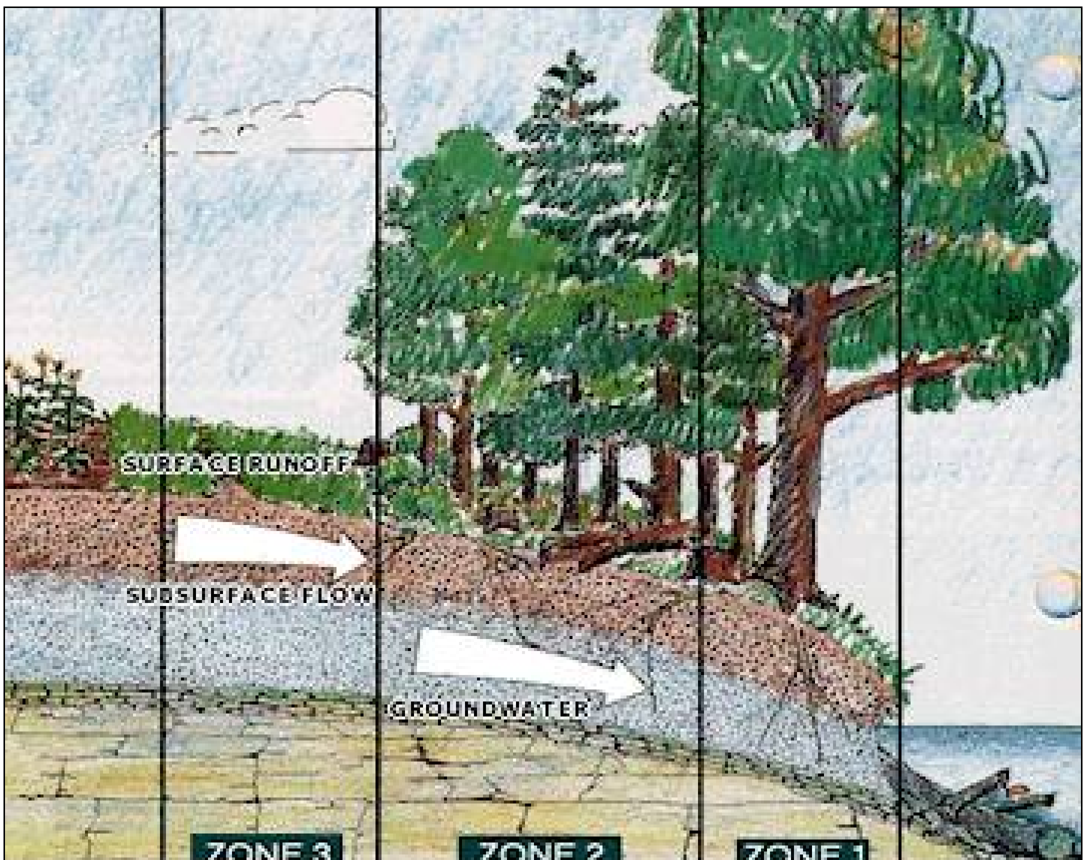
TABLE 3-8. GRASS FILTER STRIP COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Surveying	Labor to inspect and maintain the filter strips	Document maintenance	BMP overhead
Filter strip design	Soil amendment/seed materials	Environmental management plan development and maintenance	Range downtime
Planning	Mowing and spreading equipment rental		
Contracting			
Construction permitting (primarily grading activities)			
NEPA documentation			
Labor for filter strip installation			
Material for filter strip installation			
Equipment rental			

NEPA = National Environmental Policy Act.

Riparian Buffer Zones

Description: Riparian buffer zones are natural or restored areas adjacent to streams, lakes, or wetlands that provide a physical separation of these water resources from range activities. These zones can provide a storm water management function similar to grass filter strips while maintaining the ecosystem and habitat of the water resource. These zones have been found to be effective in removing sediment, nutrients, and pollutants in storm water and groundwater (ref 31). As shown in Figure 3-5, the zone closest to the water resource (Zone 1) consists of the mature natural forest area with the deep-rooted trees and plants that provide stabilization to the bank. Zone 2 is a transition zone, which may be either forested or grassed to suit site conditions. Zone 3 is a managed grassed filter strip, as described in the previous BMP, designed to catch the bulk of the sediments and munitions constituents leaving the range areas.



Sketch of a typical riparian forest buffer (Source: Chesapeake Bay Program, 2000)

Figure 3-5. Riparian buffer zones.

Benefit: Natural and restored buffer areas improve soil quality and stabilize stream banks. The extensive root systems of natural plant communities add organic matter to the soil as plant parts die and are replaced. This organic matter acts as a food source for the soil microbes that fix nitrogen and improve soil physical properties to allow water to infiltrate the soil. Stream banks in healthy riparian zones are stabilized by the permanent woody roots. The deep-rooted trees and plants in Zone 1 may provide a means of uptake or sequestration of dissolved metals; however, no data have been collected on small arms ranges to support this theory. The riparian system provides a natural, low-maintenance means of catching the sediments and munitions constituents leaving the range areas.

Applicability: Riparian buffer zones can be widely used where range boundaries and impact areas are located near surface water resources.

Limitations: For the buffer zones to perform effectively, sheet flow must be maintained through the zones. This may be difficult, especially on steep grades, where water may concentrate. Space limitations between the range boundaries and the water resources may limit establishment of effective buffer zones. In addition, buffer zones established in nondudded impact areas may be in the line of fire from the small arms ranges. These areas would be subjected to constant damage that may limit their buffering capacity.

Implementation Guidance: Prior to establishing or making riparian zone improvements, the installation environmental office should be consulted to determine local permit and construction guidelines. These buffer zones should not be installed without a design based on an engineering survey and layout to ensure maximum effectiveness. The basic design considerations for riparian buffer zones are similar to those for grassed filter strips.

- The length of the drainage area over which sheet flow travels to reach the buffer zone must be less than 150 feet to minimize flow concentration.

- Buffer zones should be established on low slopes to minimize flow concentration.

- Soils should be amended as necessary to support plant growth (see the BMP for establishing vegetative cover for soil amendment and seeding guidance).

- The minimum base for the riparian buffer should be at least 100 feet wide. Zone 1 and the filter strip in Zone 3 should each be at least 25 feet wide.

Factors that enhance and reduce performance of riparian buffer zones are presented in Table 3-9 (ref 31). The performance enhancing factors identified in Table 3-9 should be incorporated into the design of the riparian zone.

The design requirements identified here are based on the buffer zone guidance provided by the USEPA (see ref 31 for additional guidance on buffer zone design and application).

TABLE 3-9. RIPARIAN BUFFER ZONE PERFORMANCE ENHANCING/REDUCING DESIGN FACTORS[a]

Factors that Enhance Performance	Factors that Reduce Performance
Slopes <5 %	Slopes >5 %
Contributing flow lengths <150 ft	Overland flow paths >300 ft
Water table close to surface	Groundwater far below surface
Check dams/level spreaders	Contact times <5 minutes
Permeable but not sandy soils	Compacted soils
Growing season	Nongrowing season
Long length of buffer or swale	Buffers <10 ft
Organic matter, humus, or mulch layer	Snowmelt conditions, ice cover
Small runoff events	Runoff events >2-year event
Entry runoff velocity <1.5 ft/s	Entry runoff velocity >5 ft/s
Swales that are routinely mowed	Sediment buildup at top of swale
Poorly drained soils, deep roots	Trees with shallow root systems
Dense grass cover, 6 in. tall	Tall grass, sparse vegetative cover

[a]Modified from Reference 31. (Source: USEPA, 2004)

Maintenance Requirements: Generally, Zone 3, and possibly Zone 2, of the riparian buffer zone will require the same maintenance as the vegetative cover. Soils should be tested each spring to determine nutrient addition requirements. Particular attention should be paid to areas where symptomatic color or lack of plant growth suggests a soil deficiency. Fertilizers should be applied in the spring. When mowing is required, a 4- to 6-inch grass height should be maintained. Annually and after major storm events, the areas should be inspected for signs of erosion (rill and gully formation). If erosion is occurring, the eroding areas should be repaired and reseeded. In addition, sediment that may have built up around or within Zone 3 should be removed. Zone 1 should require no maintenance unless stream bank erosion occurs prior to the establishment of a mature stand of trees and vegetation. In this case, other stream bank stabilization methods may need to be implemented until Zone 1 is established. If prescribed burning is used to reduce vegetation fuel loads in range areas, do not burn the vegetation in the riparian buffer zones.

Cost Elements: The successful use of riparian buffer zones to remove sediment and lead in small arms range runoff water requires storm water management designs by an experienced engineer. The typical cost elements associated with this BMP are presented in Table 3-10. The major factors that can affect the performance and cost of this BMP are improper design for runoff conditions and improper maintenance of Zone 3 filter strip vegetation.

TABLE 3-10. RIPARIAN BUFFER ZONE COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	Annual Operation and Maintenance		
Surveying	Labor to inspect and maintain the riparian zone	Document maintenance	BMP overhead
Riparian zone design	Soil amendment and seed materials	Environmental management plan development and maintenance	Range downtime
Planning	Mowing and spreading equipment rental		
Contracting			
Construction permitting (primarily grading activities)			
NEPA documentation			
Labor for riparian zone installation			
Material for BMP installation			
Equipment rental			

NEPA = National Environmental Policy Act.

Erosion Control Mats and Mulches

Description: Erosion control mats and mulches are temporary erosion control practices used to stabilize exposed slopes and channels or recently planted soil surfaces (fig. 3-6; ref 32). Synthetic erosion control mats are also available for permanent erosion control applications in conjunction with the establishment of vegetation. Mulch and erosion control mats assist plant growth by holding seeds, fertilizer, and topsoil in place. They also retain moisture, insulate plant roots from extreme temperatures, and prevent birds from eating seeds (ref 33).

Figure 3-6. Erosion control mat and hay mulch.
(Source: ERDC-CERL, 2004)

Benefit: Mulch and erosion control mats provide temporary erosion control during the establishment of vegetation. Measured reductions in soil loss and runoff velocity are presented in Table 3-11. Permanent erosion control mats reinforce vegetation to control erosion in areas where vegetation alone would be overcome by high-flow erosive forces.

Applicability: Temporary erosion control mats and mulch are applicable where newly seeded soils require temporary erosion control until a stand of vegetation is established. Synthetic permanent erosion control mats in conjunction with vegetation are applicable where runoff flow velocities or erosive scouring forces exceed the limits of natural or man-made fiber mats, mulches, and vegetation alone. Guidance on the conditions under which mulches, temporary mats, and permanent mats are applicable is provided in Figure 3-7 (ref 34). Although permanent erosion control mats are most effective when used in vegetated areas, they can also be used as a standalone method of erosion control in arid, semiarid, and high-altitude areas where vegetation growth is limited. These erosion control measures are not typically limited by range design or use.

TABLE 3-11. MULCH SOIL LOSS AND RUNOFF VELOCITY REDUCTIONS[a]

Mulch Characteristics	Soil Loss Reduction, %	Water Velocity Reduction, % relative to bare soil
100 % wheat straw/top net	97.5	73
100 % wheat straw/two nets	98.6	56
70 % wheat straw/30 % coconut fiber	98.7	71
70 % wheat straw/30 % coconut fiber	99.5	78
100 % coconut fiber	98.4	77
Curled wood fibers/top net	90.4	47
Curled wood fibers/two nets	93.5	59
Antiwash netting (jute)	91.8	59
Interwoven paper and thread	93.0	53
Uncrimped wheat straw, 2242 kg/ha	84.0	45
Uncrimped wheat straw, 4484 kg/ha	89.3	59

[a]Modified from Reference 33. (Source: USEPA, 2004)

Limitations: Natural or manufactured fiber mats and mulches are limited to temporary erosion control situations where low-flow and low-slope conditions exist. Mulching, matting, and netting might change soil surface temperatures, which may delay seed germination. Large storms may wash the mulch away, thus requiring reapplication of seed and mulch. Permanent mats are not applicable to highly erosive flow conditions (>25 ft/s), as shown in Figure 3-7. They should not be used to prevent slope failure from causes other than superficial erosion. Their use on impact berms should be limited to those areas outside the direct impact areas of the small arms rounds.

Implementation Guidance: Erosion control materials are available to support soil stabilization and vegetation establishment efforts. In general, erosion control materials can be divided into two large categories: temporary (degradable) materials, and permanent (nondegradable) materials.

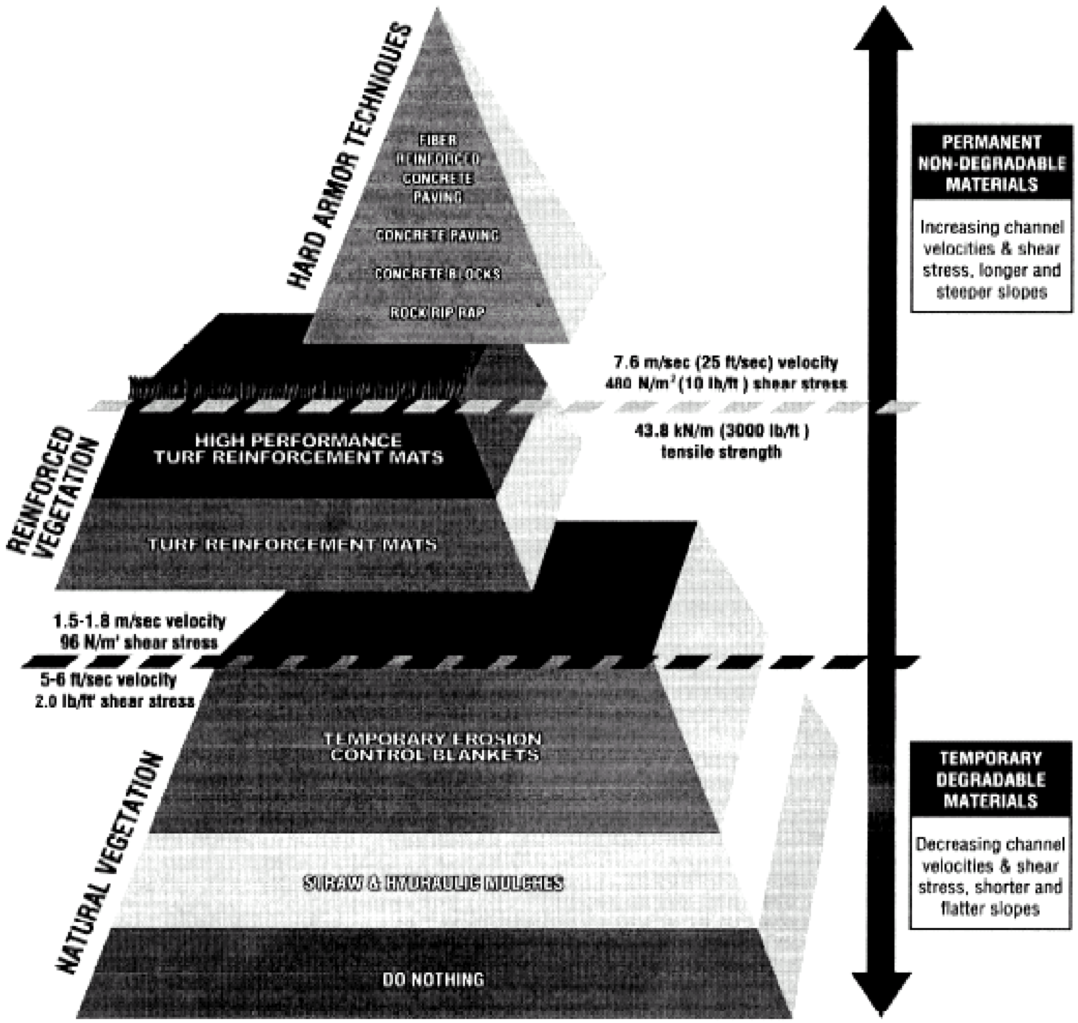


Figure 3-7. Erosion control application criteria.
(Source: USEPA, 1999)

Temporary erosion control materials are designed to provide immediate soil erosion protection and promote vegetation establishment on moderate slopes and low-flow channels where seeding may fail because of erosion. These materials are recommended in all range seeding operations to aid in the establishment of plant growth. As shown in Figure 3-7, mulch followed by erosion control blankets is recommended as a temporary means of controlling erosion until vegetation is established to maintain erosion control. Organic mulches are recommended over man-made mulches (shredded rubber, plastic, etc.) with the exception of paper. Some typical mulches and mulch mattings with application rates and methods are presented in Table 3-12. Mulch should be free of weeds and anchored by applying tackifier or netting on top to prevent loss by wind or runoff. Materials heavy enough to stay in place (e.g., bark, wood chips) on flat slopes may not need anchoring.

TABLE 3-12. TYPICAL MULCH AND MULCH MATTINGS[a]

Material	Rate per Acre	Requirements	Notes
Organic Materials			
Hay/straw	1 to 2 tons	Dry unweathered; avoid weeds.	Spread by hand or machine; must be tacked or tied down.
Wood fiber or wood cellulose (paper)	1/2 to 1 ton		Use with hydroseeder; may be used to tack straw. Do not use in hot, dry weather.
Wood chips	5 to 6 tons	Air dry. Add nitrogen fertilizer, 12 lb/ton.	Apply with blower, chip handler, or by hand. Not for fine turf areas.
Bark	35 yd^3	Air dry, shredded, or hammer milled; or chips.	Apply with mulch blower, chip handler, or by hand. Do not use asphalt tack.
Agricultural silage	1 - 2 tons	Dry, shredded, avoid weeds.	Spread by hand or machine; must be tacked or tied down.
Nets and Mats			
Jute net	Cover area	Heavy, uniform; woven of single jute yarn. Used with organic mulch.	Withstands water flow.
Wood fiber mat	Cover area		

[a]Modified from Reference 33. (Source: USEPA, 2004)

Permanent erosion control mats combine vegetative growth with synthetic materials to form a high-strength mat that prevents soil erosion. Permanent erosion control mats enhance the natural ability of vegetation to permanently protect soil from erosion. They raise the threshold of natural vegetation to withstand higher hydraulic forces. This reinforced vegetation is designed to be applied to high-volume and high-velocity storm water runoff in channels and on steep slopes. Temporary erosion control blankets and mats are biodegradable and eventually leave vegetation unprotected and without reinforcement. These should only be used to establish vegetation under mild hydraulic situations (ref 34).

Permanent erosion control mats are composed of interwoven layers of nondegradable geosynthetic materials (e.g., polypropylene, nylon, polyvinyl chloride) stitched together to form a three-dimensional matrix (fig. 3-8). The mats are thick and porous to allow soil filling and retention. A variety of anchoring devices can be used to secure erosion control mats, including u-shaped wire staples, metal pins, and wood or plastic stakes. Anchoring device selection should be based on the site-specific soil and slope conditions.

Figure 3-8. Permanent erosion control mat structure.

TIP:

Refer to the following SEDSPEC Web address for other general temporary and permanent erosion control blanket installation guidance: http://owww.cecer.army.mil/ll/sedspec/design/DisplayMeth.cfm?PKeyMethod=87&FROMUSE=8&PKEYPRACTICE=6 (ref 32). In addition, erosion control information can be procured from the International Erosion Control Association at http://ieca.org and the Erosion Contol Technology Council at http://www.ectc.org.

Maintenance Requirements: Mulched areas should be inspected frequently, especially after storm events, for washout and erosion. Eroded areas should be repaired and reseeded and mulch should be replaced as needed. Inspections should continue until a stable vegetation stand has established. Erosion control blankets and mats should be inspected quarterly and after major storm events and repaired as needed.

Cost Elements: The successful use of mats and mulches to control erosion and establish vegetation requires frequent inspection and maintenance until the vegetation has established. The typical cost elements associated with this BMP are presented in Table 3-13. The major factors that can affect the performance and cost of this BMP are land grading for runoff conditions and improper mat or mulch maintenance until the vegetation has established.

TABLE 3-13. EROSION CONTROL MATS AND MULCH COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Planning	Labor to inspect and maintain mats or mulch		Range downtime
Contracting	Mat, mulch, and seed to repair damaged areas		
Labor for mat/mulch installation			
Mat/mulch material			
Equipment rental			

3.2.3 Storm Water Management

Storm water management to improve runoff quality from ranges or range areas is the most effective overall range sustainment effort that can be performed by an installation on an active range. Storm water runoff represents the predominant mechanism for transporting the greatest volume of pollutants (lead residues and eroded soils/sediments) the most quickly and for the greatest distances. It also represents the media and quickest pathway for impacting human or ecological health by potentially introducing range pollutants into nearby surface water resources. Effective storm water management is often achieved from a management systems approach; that is, sediment and lead migration control may require two or more BMPs working together to achieve the desired effectiveness (ref 35). The establishment and maintenance of vegetation on the berm, in impact areas, and in storm water pathways has already been discussed. Other storm water management methods are presented below.

Flow Diversion - Flow diversion methods may be used to prevent storm water from impact berms or areas that have the highest potential for erosion from flowing onto comparatively clean range areas or mixing with storm water from the clean areas. This will minimize the land area impacted by mobilized munitions constituents in the runoff and the volume of contaminated runoff requiring management. Flow diversion may be accomplished by

- land shaping, and
- diversion channels (ditches, swales, and small dikes).

Runoff Velocity Reduction - Temporary and permanent methods of lowering runoff velocity and promoting sheet flow of runoff water over the range surface are available. Lowering the water velocity will lower the water's sediment load-carrying capacity and reduce the potential for erosion on the range floor that may occur with channeled flow. Runoff velocity reduction may be addressed by the flow diversion methods identified above. Other runoff velocity reduction methods include

- check dams,
- turnouts and level spreaders, and
- riprap aprons.

Sediment Trapping/Containment - Methods of trapping and containing the sediment suspended in the runoff may be used to manage storm water in areas where the runoff waters have the highest potential for carrying sediments and lead residues. These methods must be designed and sized properly to effectively slow the water and allow the suspended solids to settle out. Often, range space is limited and may not have the capacity for these types of structures. Furthermore, they can be expensive to build and maintain. Discharges from sediment trapping and containment methods may require controls, depending on the manner of discharge. These types of BMPs should be viewed as a storm water management method of last resort for range applications. Sediment trapping and containment may be accomplished by the use of

- sediment barriers,
- dry detention ponds, and
- sand filters.

In addition to the storm water controls identified above, methods of controlling dust on the range have been identified to address dust generation resulting from either BMP construction activities or normal live fire range use. Dust control as well as each of the storm water control BMP methods identified above will be addressed subsequently; the design basis for all of these methods is discussed below.

Storm Water Control Structure Design Basis

To design effective storm water BMPs, the appropriate storm characteristics must be used as the basis for the designs. A "design storm" is a specified rainfall depth and duration used to estimate erosion, runoff, peak flow rate, and sediment transport. Design storms are specified by frequency and duration. Frequency is the average interval between occurrences, and duration is the length of time over which the rainfall occurs (ref 36). A 10-year design storm frequency should be adequate for most small arms range BMP applications. This frequency was chosen as a balance between the risk of BMP failure and the construction and maintenance costs of the BMPs (ref 36).

The duration of the design storm is usually chosen to be equal to or greater than the time of concentration (T_C) for a watershed. The T_C is the estimated time (minutes) for storm water runoff to flow from the most remote part of the watershed to the outlet. The T_C consists of the total time for overland sheet flow and concentrated (channel) flow. A nomograph (app C) can be used to determine the overland portion of flow time. The concentrated channel flow time can be estimated by dividing the distance (ft) by the average velocity (ft/min) in the channel (ref 37). The duration is then used, along with the 10-year storm frequency, to determine the rainfall depth. Rainfall depths for durations from 30 minutes to 24 hours and frequencies from 1 to 100 years are available from the Department of Commerce (ref 38). The calculations to determine T_C as well as to determine the appropriate runoff coefficient and rainfall intensity for the following calculation of runoff volume require considerable engineering experience and should be performed by a qualified engineer specializing in storm water runoff problems.

Storm water runoff volumes for small drainage areas are typically calculated using the rational method, which is used to predict the peak runoff rates based on rainfall intensity and knowledge of land use in the drainage area. This method is particularly useful for small drainage areas of 50 acres or less and should be applicable to the subwatersheds of most small arms ranges (ref 37). The rational method formula is

$$Q = CiA$$

where:

- Q = peak runoff rate (cubic feet per second (cfs)).
- C = runoff coefficient, an empirical coefficient representing the relationship between rainfall rate and runoff rate.
- i = average rainfall intensity (in./hr) for a storm duration equal to the time of concentration, T_C (min).
- A = drainage area (acres).

The runoff coefficients (C) for agricultural land presented in Table 3-14 may be used to estimate an appropriate C for the drainage area. If the land cover is not homogeneous for the drainage area, then a weighted average for the C can be calculated based on the area for each type of cover (ref 39). Although runoff coefficients have not been established specifically for training range areas, the surface cover and soil characteristics presented in Table 3-14 can be used to approximate the land conditions seen in range areas to support the determination of a range runoff coefficient.

TABLE 3-14. RUNOFF COEFFICIENTS FOR AGRICULTURAL LAND

Surface Cover	Soil Characteristic	Runoff Coefficient (C)
Bare packed soil	Smooth	0.30 to 0.60
	Rough	0.20 to 0.50
Cultivated rows	Heavy	0.30 to 0.60
	Heavy	0.20 to 0.50
	Sandy	0.20 to 0.40
	Sandy	0.10 to 0.25
Pasture	Heavy	0.15 to 0.45
	Sandy	0.05 to 0.25
	Woodlands	0.05 to 0.25

Rainfall intensity can be obtained from intensity-duration-frequency curves developed by various State and Federal agencies (ref 39). Once this information has been used to estimate the peak runoff, rate selection and design of appropriate storm water BMPs can be performed.

Land Shaping

Description: Land shaping involves making subtle changes in grade in flow paths to promote a dispersion of runoff flow over a larger area (sheet flow). Promoting sheet flow will reduce the flow rate of the runoff. Promoting sheet flow over range surfaces is typically accomplished by methods such as grading and flattening the slope of the land or by creating broad, very shallow drainage pathways to replace ditches or deep, narrow channels. The latter method must be coupled with an effort to establish vegetation to minimize the tendency for the flow to cut new channels in the area.

Gradient terraces are another form of land shaping. In areas that have long, steep slopes with erosion problems, gradient terraces can be incorporated into a range design to reduce the velocity and direction of storm water flow. Terraces could be used to stabilize the slopes and direct water flow to areas that are not impacted by rounds.

Benefit: Land shaping and terracing will lower runoff velocity, minimize erosion, and reduce the sediment load-carrying capacity of the runoff.

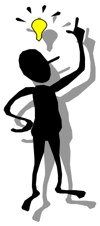
Applicability: Land shaping is applicable to range areas that currently have low slopes, little or no vegetation, and pronounced gullying or channeling of storm water runoff. Land shaping can be applied to a wide variety of range types that meet these general topographic criteria. Generally, rounds impacting in an area that has been shaped will not interfere with the performance of the BMP.

Terracing is generally applicable for use on long, steep slopes with erosion problems and no vegetation. It is not applicable for slopes that are used as backstops for ranges.

Limitations: As the natural slope of the land increases, the viability of using land shaping decreases because of the increased construction costs associated with soil movement as well as the additional need for inlet and outlet transition structures to control dispersion of the runoff flow.

Gradient terraces are not appropriate for sandy or shallow soils (minimal depth to bedrock), rocky soils, or short steep slopes. If too much water permeates the soil, sloughing and excessive erosion could destabilize the terrace system. Gradient terraces are similarly not suited for installation in range impact areas. The disturbance caused by the rounds impacting the terrace system could result in sloughing and erosion during rain events that would destabilize the terrace system.

Implementation Guidance: Prior to making drainage improvements, the installation environmental office should be consulted to determine local permit and construction guidelines. Land shaping and gradient terraces should not be installed without a well-developed design based on an engineering survey and layout. Appropriate outlets should be included in the plan. The preferred outlet for range applications is a grassed waterway. The outlets should be directed away from the areas where the rounds impact and toward areas that are not susceptible to erosion. In addition to the outlets, vegetative cover should be established in all areas where soil has been disturbed by construction activities.



TIP:
Refer to the following SEDSPEC Web address for other general land shaping construction considerations: http://owww.cecer.army.mil/ll/sedspec/design/DisplayMeth.cfm?PKeyMethod=16&FROMUSE=10&PKEYPRACTICE=6 (ref 40).

Maintenance Requirements: Annual inspections and inspections after major storm events for erosion damage should be conducted. Any necessary repairs should be made to maintain performance.

Cost Elements: The successful use of land grading to control erosion and lead migration in small arms range runoff water requires storm water management designs by an experienced engineer. The typical cost elements associated with this BMP are presented in Table 3-15. The major factors that can affect the performance and cost of this BMP are improper design for runoff conditions and improper maintenance of the designed land grade.

TABLE 3-15. LAND SHAPING COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Surveying	Labor to inspect and maintain the designed land grade	Document maintenance	BMP overhead
Land grade design	Consumable materials	Environmental management plan development and maintenance	Range downtime
Planning			
Contracting			
Construction permitting			
NEPA documentation			
Labor for grading			
Material for grading support (e.g., fill dirt)			
Equipment rental			

NEPA = National Environmental Policy Act.

Diversion Channels and Dikes

Description: Diversions can be used to intercept and divert excess or overland flow away from the small arms round impact points and areas susceptible to erosion. The diversions subdivide the landscape into smaller drainage areas that provide smaller volumes of runoff to manage. The flow can be diverted to areas where it can be released without land or water quality degradation. Diversions can be ditches or swales with a parabolic or trapezoidal contour. They can also be a ridge/berm/dike with or without an accompanying swale. Diversions can be constructed in a number of ways to accommodate various site conditions and available construction materials.

Benefit: The runoff water from an impact berm or other area where rounds impact has significantly higher lead concentrations and suspended sediments loads than runoff from areas such as the firing positions and range floor. Flow diversions can direct flow around these areas, thus minimizing the amount of runoff that may carry munitions constituents off-range. Minimization of potentially contaminated runoff allows other BMPs designed to promote sediment deposition or filtering of the flow to perform more efficiently.

Applicability: Flow diversions are particularly effective at the base of impact berms located behind targets, as are often found on 25-meter ranges (FCC 17801). They may be effectively applied to direct flow around known concentrated impact points within the impact area (if nondudded). Flow diversions may also be applied on ranges to direct flow around concentrated impact points in front of or behind automated targets on ranges such as the AFF (FCC 17803), ARF (FCC 17805), and MRF (FCC 17806). Diversions would be used on these ranges only if overland flow occurs in sufficient volumes and flow rates to mobilize sediments from their impact points.

Other general applications (ref 39) of diversions are as follows:

- where runoff can be diverted or released without erosion or sedimentation damage.
- on or above steep or long slopes to prevent gully erosion.
- on or above steep or long slopes that provide runoff and sediment to drainage ditches.
- below steep or long grades where sediment deposition may occur.
- around areas subject to damage from runoff or sediment deposition.
- around areas subject to internal degradation (e.g., training or testing activities) to prevent movement of sediment-laden runoff to adjacent properties or water bodies.

A typical application of diversions to protect a hillside being used as a backstop to capture rounds is shown in Figure 3-9. This application would minimize the amount of runoff flowing over the impact area on the hillside.

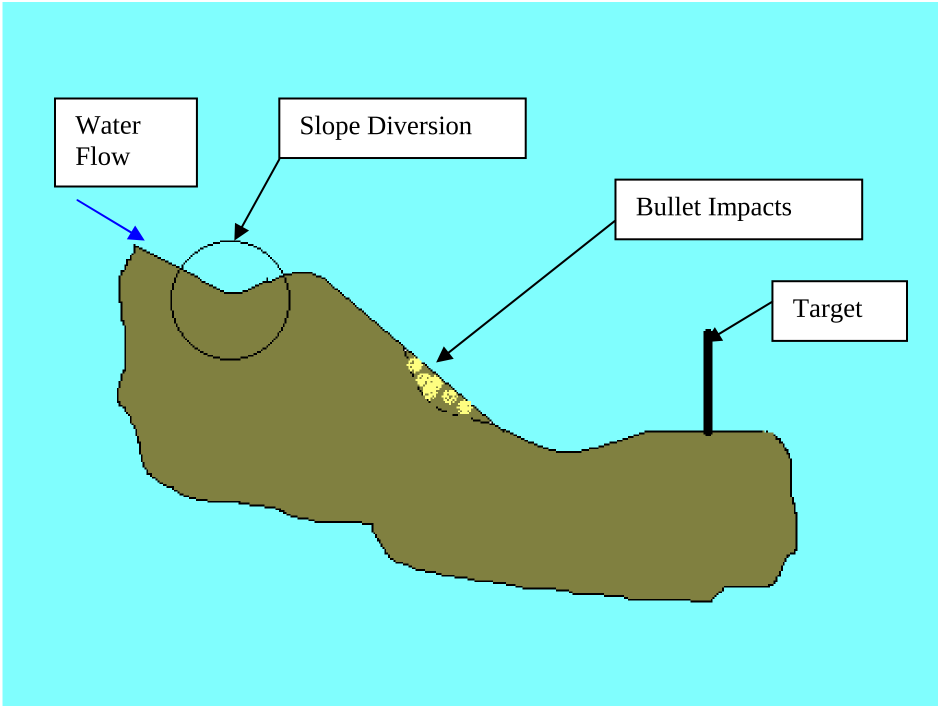


Figure 3-9. Slope diversion above hillside impact area.

Limitations: Some potential disadvantages (ref 41) of the use of flow diversions include

- potential erosion problems due to concentrated flows.
- potential groundwater contamination if diversion channels have a high infiltration capacity.
- space limitations making diversion structures impractical.

Implementation Guidance: Prior to making drainage improvements, consult with the installation environmental office to determine local permit and construction guidelines. Flow diversion for use in range areas should not be installed without a well-developed design based on an engineering survey and layout. Design considerations are as follows:

- Flow velocity, outlet stability, location, shape, and method of stabilization of the diversion should be taken into account.
- Appropriate outlets should be directed away from the areas where the rounds impact and toward areas that are not susceptible to erosion. Outlets must be designed to accept flow from the diversion and other contributing areas. Sediment-laden flow must be diverted to a sediment trap and then released at nonerosive velocities. Concentrated flow must be conveyed from the slope using chutes, drop structures, pipe and riser, or flumes, or it must be transitioned through an energy dissipation apron or onto a level spreader, where it can be released as sheet flow onto a stable vegetated area.

- Natural landscape features such as points of elevation, natural swales, and ridges should be incorporated to the maximum extent possible.

- The preferred diversion and outlet stabilization method for range applications is a grassed waterway. If flow conditions are not favorable for grass-linings, then other methods (e.g., stone, geotextiles) may be used (but not in locations that may create a ricochet hazard). Other BMPs in this manual may be referred to for vegetation and other channel lining construction guidance.

- An emergency spillway or overflow should be incorporated into the design to reduce damage to the diversion when design storms are exceeded. Typically, a riprap spillway with an apron will be adequate for this overflow.

- **Interceptor diversion dike design criteria:** Side slope: 2:1 or flatter (3:1 or flatter if mowed). Top width: 2-foot minimum. Freeboard: 1/2 foot minimum. Settlement: 10 percent of total height minimum. Compaction: The berm or dike material should be compacted to 85 percent of maximum density. An example of interceptor diversion dike designs shown in Figure 3-10 (ref 39).

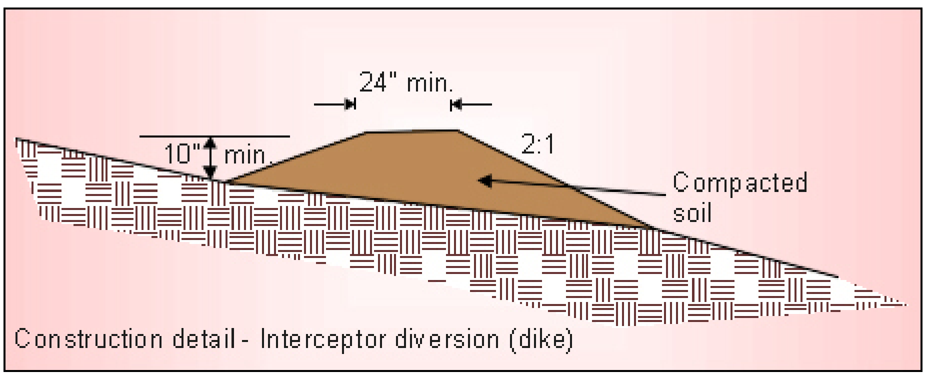


Figure 3-10. Typical diversion dike design.
(Source: ERDC-CERL, 2004)

- **Swale design criteria:** Material must meet velocity requirements. Shape: Parabolic or trapezoidal to fit site conditions. Side slope of 2:1 or flatter (3:1 or flatter if mowed).

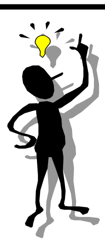
- **Velocity:** Permissible velocities within the diversions are generally the same as for grassed waterways. Maximum velocities are presented in Table 3-16.

TABLE 3-16. MAXIMUM VELOCITIES FOR CHANNEL LINING

Channel Type	Minimum Velocity, ft/s	Maximum Velocity, ft/s
Unlined earthen channel	1	2
Vegetation-lined channel	2	4
Riprap-lined channel	3	10

- **Grade:** The overall grade of the diversion should be uniform or gradually increasing. For grassed-lined swales, the minimum grade downslope is 0.5 percent and the maximum grade downslope is 2 percent. For grades greater than 2 percent, or if larger flows are anticipated, the swale requires stabilization with channel lining fabric or riprap.

- In addition to the diversions and outlets, vegetative cover should be established in all areas in which soil has been disturbed by construction activities.



TIP:
Refer to the following SEDSPEC Web address for other general diversion construction considerations: http://owww.cecer.army.mil/ll/sedspec/design/DisplayMeth.cfm?PKeyMethod=5&FROMUSE=8&PKEYPRACTICE=8 (ref 39).

Maintenance Requirements: Annual inspections and inspections after major storm events for erosion damage should be conducted. Necessary repairs should be made to maintain performance. Vegetation growth should be maintained and any obstructions or debris that have fallen in the diversions should be removed.

Cost Elements: The successful use of diversion channels and dikes to control erosion and lead migration in small arms range runoff water requires storm water management designs by an experienced engineer. The typical cost elements associated with this BMP are presented in Table 3-17. The major factors that can affect the performance and cost of this BMP are improper design for runoff conditions and improper maintenance of the channels or dikes.

TABLE 3-17. DIVERSION CHANNEL AND DIKE COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Surveying	Labor to inspect and maintain channels or dikes	Document maintenance	BMP overhead
Channel or dike design	Materials to repair damaged channels or dikes	Environmental management plan development and maintenance	Range downtime
Planning			
Contracting			
NEPA documentation			
Construction permitting			
Labor to support channel or dike construction			
Material for channel or dike construction			
Equipment rental			

NEPA = National Environmental Policy Act.

Check Dams

Description: Check dams are small dams built across drainage ditches or swales (fig. 3-11). They can be constructed using gravel, rock, sandbags, logs, or straw bales. Their primary function is to slow the velocity of the water flow to reduce bank and bottom erosion in the channel. As a secondary function, check dams may also catch sediment from the channel or contributing drainage area; however, check dams are not considered a replacement for other sediment trapping or erosion control measures. Check dams are most effective when used in combination with other erosion and sediment control measures. For long channels, check dams are most effective when used in a series to create multiple barriers to slow runoff (ref 42).

Figure 3-11. Riprap check dams installed in a roadside swale.
(Source: ERDC-CERL, 2004)

Benefit: Check dams reduce the energy of the flowing water, thus reducing its erosive scouring and sediment load-carrying capacity.

Applicability: Check dams are applicable to drainage ways to reduce flow velocity over long distances or on steep grades. They are applicable where channel erosion problems are present and channel lining or diversion measures are not practicable. Check dams may be used as temporary structures to limit erosion in newly constructed or newly seeded channels in range areas until other erosion control measures become effective.

Limitations: Check dams should not be used in live, flowing streams. The primary function of check dams is to slow runoff in a channel. They should not be used as a substitute for other sediment trapping methods. Leaves and sediment may clog the check dams, so frequent inspection and cleaning may be required. In addition, riprap check dams (or other potentially ricocheting construction materials) should not be used in any areas that may have the potential for ricochets during range use.

Implementation Guidance: Prior to making drainage improvements, the installation environmental office should be consulted to determine local permit and construction guidelines. Check dams for use in range areas should not be installed without a well-developed design based on an engineering survey and layout. Design considerations are as follows:

- Flow velocity, outlet stability, location, and check dam construction materials must be considered.

- Check dams must be constructed in series.

- Check dams must be placed in reasonably straight reaches of the ditch.

- When selecting construction materials, site and foundation conditions must be considered.

- Construction materials may include riprap, gabions, wood, logs, or other durable materials. Straw bales, straw bale/filter fabric, filter fabric/fence, or filter fabric alone are forms of sediment barriers. They may be used temporarily across or within gentle swales with low flow to trap sediment, but they should not be placed across a drainage ditch carrying a high-volume flow or high-velocity flow. If the flow in the ditch exceeds the capacity for a grass lining, sediment barriers must not be placed across the ditch or outlet.

- The design channel grade above and below the check dam must be evaluated to determine the potential for erosion or sediment deposition. In gullies with gradients of less than 20 percent, the slope of the expected deposits should be 0.7 percent of the original gully gradient. In gullies with gradients greater than 20 percent, the slope of the expected deposits should be reduced to 0.5 percent of the original gradient.

- The maximum height of the spillway (center of check dam) should be no more than 2 feet above the bed of the ditch. The center of the spillway crest (weir notch) should be 9 inches lower than the ditch banks at natural ground level, and at least 6 inches lower than the adjacent edges of the structure.

- The check dam should be keyed into the bottom and sides of the channel. The keyway should be excavated a minimum of 2 feet wide, 12 inches deep, and 18 inches into each side bank. This entrenchment provides stability and prohibits undermining or side scour.

Specific construction guidance based on the material of construction is presented below.

<u>Riprap Check Dam</u>

- Maintain the channel side slopes of 2:1 or flatter for riprap check dams.

- Ensure that the maximum spacing between the dams is such that the toe of the upstream dam is at the same elevation as the top of the downstream dam (ref 42). Optimal check dam spacing is shown in Figure 3-12.

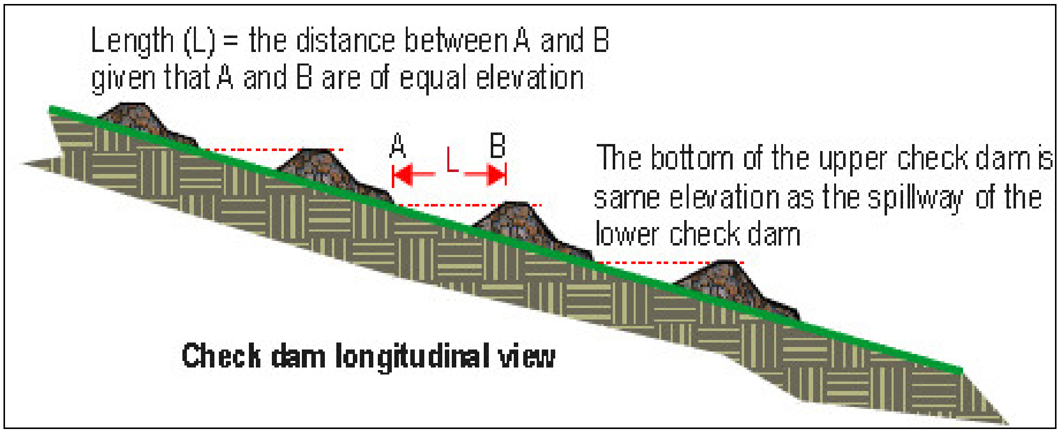


Figure 3-12. Spacing of check dams in a series.
(Source: ERDC-CERL, 2004)

- Use 4- to 15-inch well-graded stone to construct riprap check dams and aprons.

- Install a heavy-duty filter fabric between the keyway, apron, and riprap.

- Keep the spillway section at least 6 inches lower than the outer edges.

- Dump the riprap onto the check dam to allow the stones to attain their natural angle of repose.

- Check the riprap for voids, and hand place stones as necessary to minimize voids. Voids will reduce the effectiveness of the dams.

<u>Log Check Dam</u>

- Line the check dam and apron with filter fabric to prevent undermining.

- Drive posts 2 to 4 feet into the channel bottom, spaced about 4 feet apart, with the tops extending 2 to 3 feet above the ground.

- Upstream of the log posts, excavate a keyway trench across the channel the width of a log and three quarters of the diameter of a log that will be placed in the ditch. Extend the keyway into the side banks 18 to 24 inches.

- Lay logs on top of the anchor log until they reach the top of the upright posts.

- Secure the horizontal logs by nailing them to the upright posts, driving small stakes on the upstream side near their ends, or compacting the bank soil against the entrenched ends.

- Cut a weir notch at the center of the dam.

- Install an apron below the dam. Logs can be laid side-by-side and secured with stakes at the lower end. Loose rock can also be used if secured by a log that is set three quarters of the diameter into a trench across the channel bottom about 4 to 6 feet below the dam.

- A log check dam is shown in Figure 3-13.

Figure 3-13. Log check dam. (Source: ERDC-CERL, 2004)

Straw and Sandbag Check Dams

- When using straw bales as temporary check dams, place them in a single row, within a keyway trench, tightly fitted end-to-end and lain perpendicular to the flow (fig. 3-14).

- Extend the bales across the channel, gully, or ditch far enough to prevent water or sediment from going around the ends.

- Lay the straw bales at least 4 inches into the keyway trench.

- Fill any gaps in the straw with more straw, rocks, or filter fabric, and tamp well to prevent undercutting.

- Secure bales with two stakes, each driven at least 18 inches into the ground.

- Use a riprap apron below the dam to prevent undermining.
- Install sandbags in a manner similar to the straw bales (fig. 3-15).

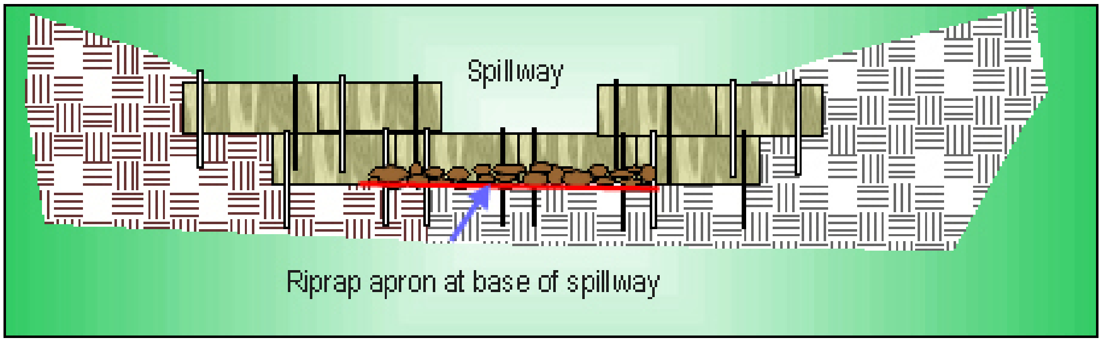


Figure 3-14. Straw bales used in check dams. (Source: ERDC-CERL, 2004)

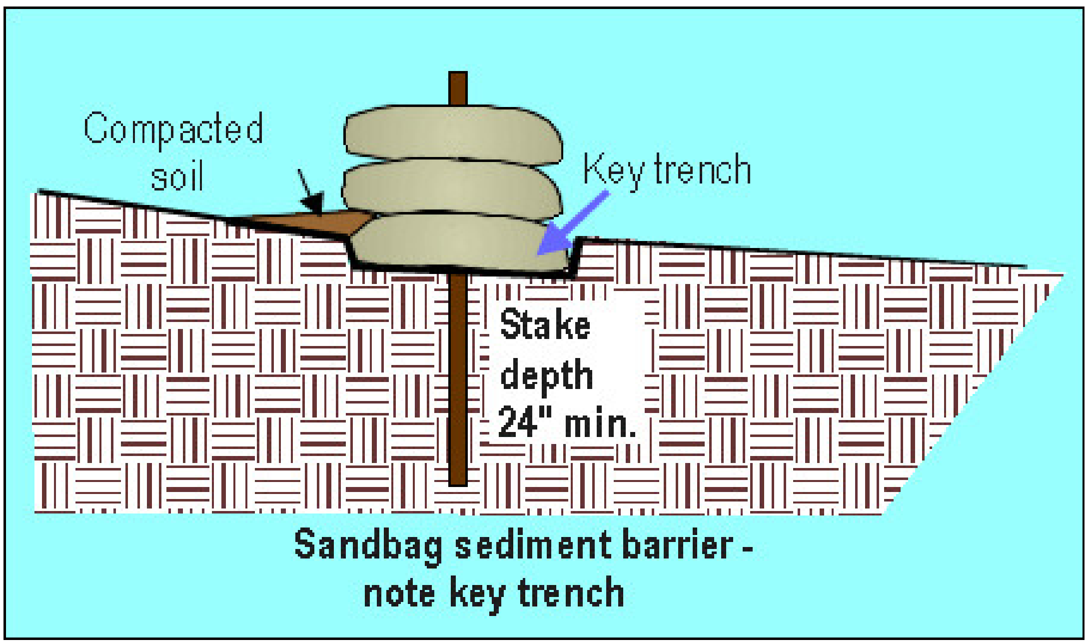


Figure 3-15. Sandbags used in check dams. (Source: ERDC-CERL, 2004)

TIP:
Refer to the following SEDSPEC Web address for other general check dam designs and construction considerations: http://owww.cecer.army.mil/ll/sedspec/design/DisplayMeth.cfm?PKeyMethod=3&FROMUSE=8&PKEYPRACTICE=8.

Maintenance Requirements: Quarterly inspections and inspections after major storm events should be conducted to ensure performance effectiveness, and necessary repairs should be made to maintain performance. Accumulated sediment and debris should be removed from the upstream side of the check dam.

Cost Elements: The successful use of check dams to reduce runoff velocity in channels or swales to control erosion requires adequate storm water management designs by an experienced engineer. The typical cost elements associated with this BMP are presented in Table 3-18. The major factors that can affect the performance and cost of this BMP are improper design for runoff conditions and improper maintenance of the check dams.

TABLE 3-18. CHECK DAM COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Surveying	Labor to inspect and maintain check dams	Document maintenance	BMP overhead
Check dam design	Materials required to repair check dams	Environmental management plan development and maintenance	Range downtime
Planning			
Contracting			
Construction permitting			
NEPA documentation			
Labor to support check dam installation			
Material to support check dam installation			
Equipment rental			

NEPA = National Environmental Policy Act.

Channel Stabilization

Description: Channel stabilization is often needed in range areas to control erosion and sediment transport in storm water runoff. The channels may be either man-made or naturally cut in the runoff flow path. Vegetation and check dams are methods of channel stabilization that have previously been discussed. This BMP method will focus on riprap lining as a means of stabilization (fig. 3-16; ref 43). Riprap linings stabilize, harden, and protect drainage channels from runoff erosion. The surface irregularity of riprap (and grass) linings makes them preferable to other linings because of their ability to both harden the channel and reduce the velocity of the storm water flow.

Figure 3-16. Riprap-lined channel.
(Source: ERDC-CERL, 2004)

Benefit: Riprap linings mitigate channel erosion and reduce runoff flow velocity in the channel.

Applicability: Riprap linings are applicable where channel erosion problems are present and grass lining is not practicable because of high-flow velocities (3 to 10 ft/s).

Limitations: Riprap linings should not be used in any areas having the potential for ricochets during range use. In addition, riprap linings should not be used on channel slopes greater than 2:1. Steep slopes have the potential for riprap loss due to erosion and sliding.

Implementation Guidance: Prior to making drainage improvements, the installation environmental office should be consulted to determine local permit and construction guidelines. Riprap linings for channels in range areas should not be installed without a design based on an engineering survey and layout. Design considerations are as follows:

- The peak flow that the section of channel will be expected to convey must be identified to design the channel lining and shape. The selection of the appropriate size and volume of riprap depends on a variety of factors and should be determined by an engineer.

- The shape and depth of the channel must be considered. A deep channel will require more erosion protection than a shallow one at the same flow velocity. Wider channels with gentle side slopes of 3:1 are the preferred shapes.

- Riprap should be applied to at least one and a half times the thickness of the largest stones. Riprap should be hard, durable, and weather resistant.

- A filtering layer of sand or fine gravel or a filter fabric should be securely installed between the ground and the riprap.

- Riprap should extend to a minimum height of 6 inches above the design waterline.

Typical channel shapes include parabolic, trapezoidal, and V-shaped channels. Parabolic or trapezoidal-shaped ditches are preferred to V-shaped ditches because the flow is dispersed over a wider area. V-shaped ditches concentrate runoff in the lowest portion of the channel, where incision is rapid and often extreme. Riprap application to each of these channel shapes is shown in Figures 3-17 through 3-19.

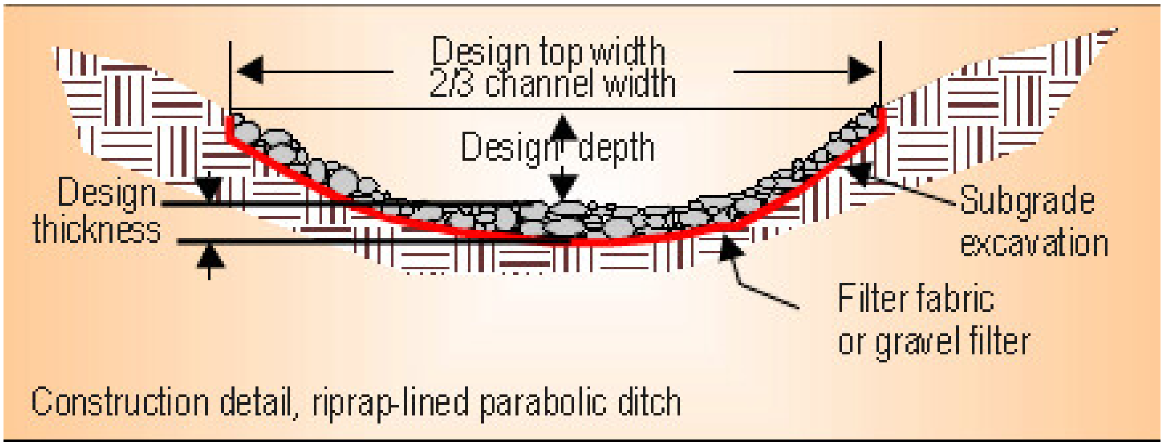


Figure 3-17. Parabolic-shaped channel.
(Source: ERDC-CERL, 2004)

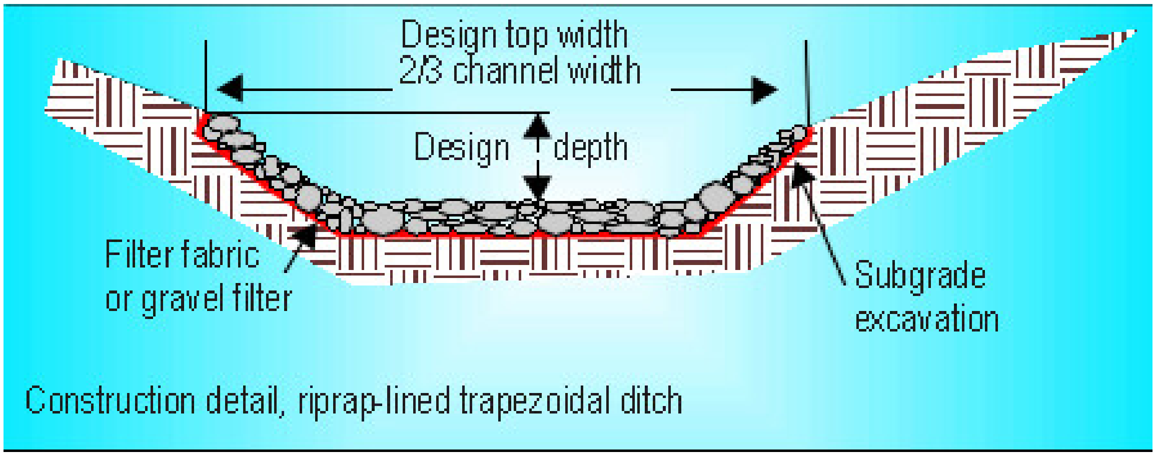


Figure 3-18. Trapezoidal-shaped channel.
(Source: ERDC-CERL, 2004)

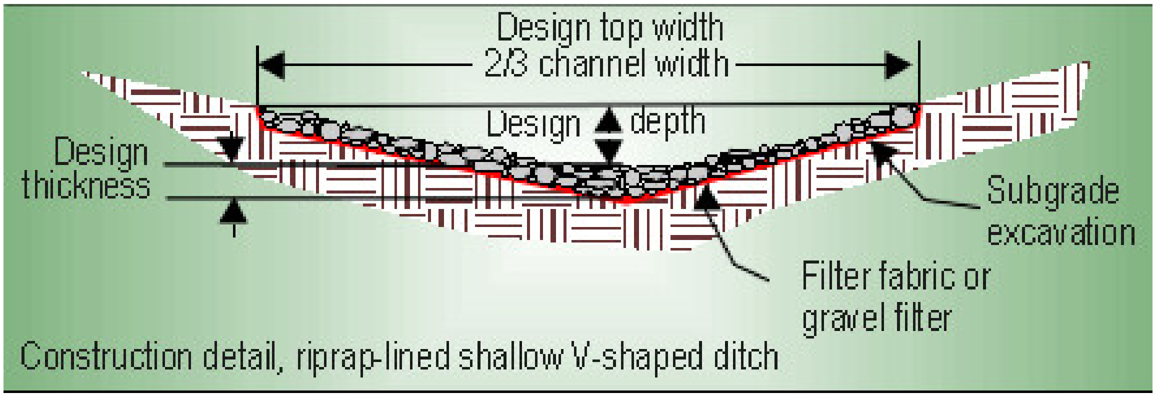
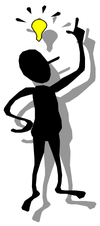


Figure 3-19. V-shaped channel.
(Source: ERDC-CERL, 2004)



TIP:
Refer to the following SEDSPEC Web address for other general riprap channel lining construction considerations: http://owww.cecer.army.mil/ll/sedspec/design/DisplayMeth.cfm?PKeyMethod=18&FROMUSE=8&PKEYPRACTICE=6.

Maintenance Requirements: Annual inspections and inspections after major storm events should be conducted for erosion scour or gullying damage, and any necessary repairs should be made to maintain performance.

Cost Elements: Successful channel stabilization that decreases runoff velocity and controls erosion requires adequate storm water management designs by an experienced engineer. The typical cost elements associated with this BMP are presented in Table 3-19. The major factors that can affect the performance and cost of this BMP are improper design for runoff conditions and improper maintenance of the channel and its stabilizing elements.

TABLE 3-19. CHANNEL STABILIZATION COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Surveying	Labor to inspect and maintain channel linings	Document maintenance	BMP overhead
Channel design	Material needed to repair channel linings	Environmental management plan development and maintenance	Range downtime
Planning			
Contracting			
Construction permitting			
NEPA documentation			
Labor to support installation of channel lining			
Material to support installation of channel lining			
Equipment rental			

NEPA = National Environmental Policy Act.

Turnouts and Aprons

Description: Turnouts and aprons are transitions from flow diversions or channels in which there are concentrated, high-velocity flows to discharges into undisturbed areas with low-velocity nonerosive flows. Turnouts can be designed with grass or riprap-lined aprons or with level spreaders.

Benefit: Turnouts and aprons convert the concentrated flow in diversions and channels to nonerosive sheet flow. They reduce the energy of the flowing water, thus reducing its erosive scouring and sediment load-carrying capacity.

Applicability: Turnouts and aprons are applicable to diversions and drainage channels in range areas where rill or gully development is present and where water is discharging from channels directly into surface water resources.

Limitations: Turnouts or aprons that use riprap linings should not be used in any areas having the potential for ricochets during range use.

Implementation Guidance: Prior to making drainage improvements, the installation environmental office should be consulted to determine local permit and construction guidelines. Guidelines for transitioning from concentrated flows to low-velocity sheet flows are provided below. Diversion or drainage channel turnouts with level spreaders are discussed first, followed by a discussion of riprap aprons. If the concentrated flows are less than 2 ft/s, the vegetation BMP section (para 3.2.2) should be consulted for guidance on the use of vegetated aprons.

Turnouts with Level Spreader Transitions

Turnouts and level spreaders in range areas should not be installed without a design based on an engineering survey and layout (fig. 3-20 and 3-21). Design considerations are as follows:

- Turnouts should be installed only where the area directly below the turnout outlet is stabilized by vegetation, where the area has been adequately hardened against erosive volumes of runoff, or where the drainage will not initiate erosion or flow directly into a water body.

- Turnouts must be constructed with a discharge slope of 2 to 3 degrees.

- The minimum turnout width should be the width of the drainage channel from which water is being diverted. The length of the transition from channel to the level spreader should be a minimum of 20 feet.

- Sediment-laden runoff should be filtered by sediment barriers or traps before it is diverted to stable areas.

- The drainage area should be restricted such that maximum flows into the level spreader do not exceed 30 cfs.

- The appropriate length spreader should be used (table 3-20).

- The grade of the last 20 feet of the turnout or diversion should provide a smooth transition from the channel grade to a level grade at the spreader. The grade of the spreader should be 0 percent.

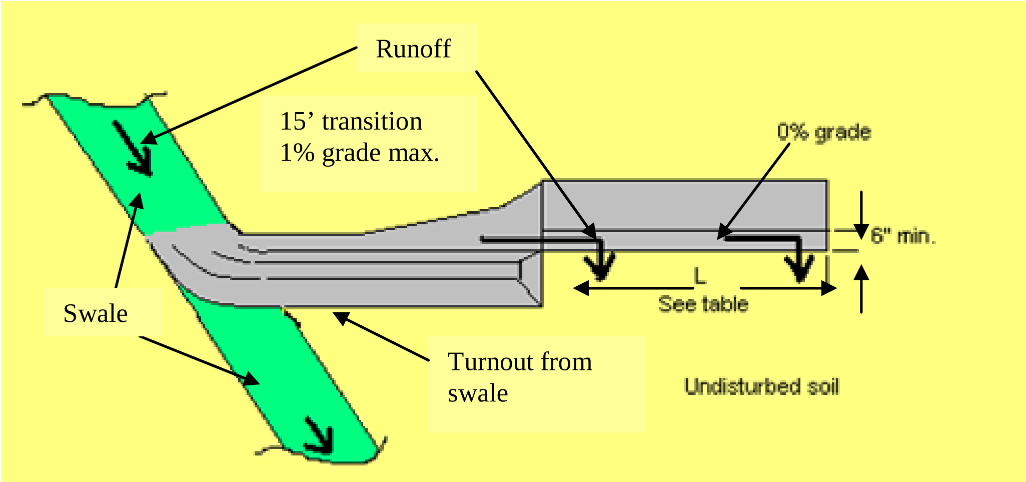


Figure 3-20. Turnout and level spreader (top view). (Modified from ref 44)
(Source: ERDC-CERL, 2004)

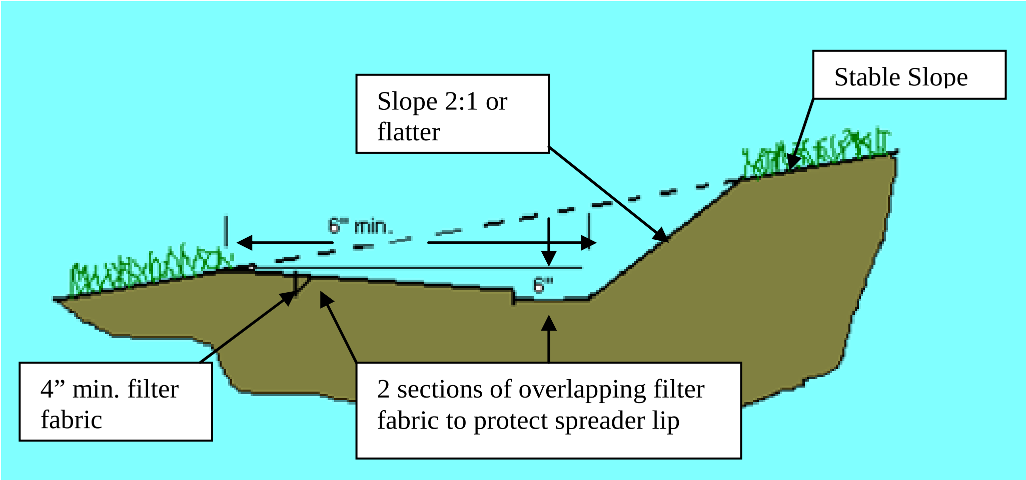
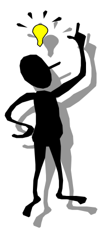


Figure 3-21. Level spreader on a slope (plan view). (Modified from ref 44)
(Source: ERDC-CERL, 2004)

TABLE 3-20. LEVEL SPREADER LENGTH VERSUS FLOW RATE

Design Q, cfs	Minimum Length, ft
0 to 10	15
10 to 20	20
20 to 30	26
30 to 40	36
50	44

Q = flow rate in cubic feet per second (cfs)

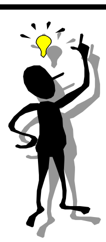


TIP:
Refer to the following SEDSPEC Web address for other general turnout and level spreader design and construction considerations: http://owww.cecer.army.mil/ll/sedspec/design/DisplayMeth.cfm?PKeyMethod=75&FROMUSE=6&PKEYPRACTICE=8 (ref 44).

Riprap Aprons

Riprap aprons in range areas should not be installed without a design based on an engineering survey and layout (ref 43). Design considerations are as follows:

- The aprons should be designed to reduce the velocity of the diversion or channel discharge to the permissible velocity of flow for the receiving area.
- The apron should have a level or zero grade.
- The top of the riprap at the discharge end of the apron should be flush with the surface of the receiving area.
- The minimum thickness of the riprap should not be less than 1.5 times the maximum stone diameter.
- The riprap stone must be hard, angular, and weather resistant.
- A sturdy filter fabric or 6- to 9-inch course of filter sand or gravel should be laid before the placement of riprap.



TIP:
Refer to the following SEDSPEC Web address for other general riprap apron design and construction considerations: http://owww.cecer.army.mil/ll/sedspec/design/DisplayMeth.cfm?PKeyMethod=31&FROMUSE=6&PKEYPRACTICE=8 (ref 45).

Maintenance Requirements: Quarterly inspections and inspections after major storm events should be conducted for erosion damage to the turnouts, level spreaders and aprons, and necessary repairs should be made to maintain performance. Excess sediment should be removed, and dislodged stones should be returned to the aprons.

Cost Elements: Successful turnouts and aprons that decrease runoff velocity and control erosion require adequate storm water management designs by an experienced engineer. The typical cost elements associated with this BMP are presented in Table 3-21. The major factors that can affect the performance and cost of this BMP are improper design for runoff conditions and improper maintenance of the channel turnouts and aprons.

TABLE 3-21. TURNOUT AND APRON COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Surveying	Labor to inspect and maintain turnouts and aprons	Document maintenance	BMP overhead
Turnout and apron design	Material needed to repair damaged turnouts and aprons	Environmental management plan development and maintenance	Range downtime
Planning			
Contracting			
Construction permitting			
NEPA documentation			
Labor to support turnout or apron installation			
Material to support turnout or apron installation			
Equipment rental			

NEPA = National Environmental Policy Act.

Sediment Barriers

Description: Sediment barriers are structures placed perpendicular to the slope of the land to decrease runoff velocity and trap sediment (ref 46 and 47). Common sediment barriers include silt fence, straw bales, and brush barriers (fig. 3-22).

Figure 3-22. Silt fence and straw bale sediment barriers.
(Source: ERDC-CERL, 2004)

Benefit: Sediment barriers can provide an effective and relatively inexpensive temporary method of controlling sediment movement.

Applicability: Sediment barriers can be used to provide temporary storm water and sediment control while other control measures are installed and allowed to establish.

Limitations: Sediment barrier use should be limited to areas where land slope is 3:1 or less and flow rates are low enough to prevent damage to the barrier (ref 48).

Implementation Guidance: Prior to making drainage improvements, the installation environmental office should be consulted to determine local permit and construction guidelines. Temporary sediment barriers for use in range areas should be installed in accordance with an approved sediment and erosion plan. General design considerations are as follows:

- Sediment barriers should be designed to handle a 10-year storm event.
- Sediment barriers should be installed perpendicular to the direction of the runoff flow.
- The drainage area for sediment barriers should be less than 1/4 acre per 100 linear feet of barrier.
- Sediment barriers should be used only to filter sediments from sheet flow and only where shallow ponding can occur. Sediment barriers should not be used in streams or channels.

- The ends of the sediment barriers should be tied into the landscape to prevent flow around the end of the barrier.

- Overflow outlets should be included in the sediment barrier design to prevent overtopping of the barrier if the barrier becomes clogged or if flow volumes exceed the design flow. A riprap apron should be provided at overflow outlets.

- Sediment barriers should be spaced based on the slope of the landscape (table 3-22; ref 48).

TABLE 3-22. BARRIER SPACING GUIDELINES

Slope, %	Barrier Spacing, ft
<2	100
2 to 5	75
5 to 10	50
10 to 20	25
>20	15

(Source: ERDC-CERL, 2004)

Specific sediment barrier construction guidance based on the material of construction is presented below.

Silt Fence

- Use silt fences composed of synthetic filter fabric or pervious polypropylene, nylon, polyester, or polyethylene sheet. Ensure that the material meets the specifications provided in Table 3-23.

TABLE 3-23. SILT FENCE MATERIAL SPECIFICATIONS

Parameter	Specification
Filtering efficiency	85 % minimum
Tensile strength at 20 % maximum elongation	Standard strength = 30 lb/linear inch Extra strength = 50 lb/linear inch
Permeability	0.3 gal/ft^2/min (minimum)
Height	3 ft (maximum)
Usable life	6 months (minimum)

- Confirm that support post spacing is a maximum of 4 feet without wire fence support and a maximum of 8 feet with wire fence support.

- Confirm that ponded water depth does not exceed 1.5 feet along the silt fence.

TIP:
Refer to the following SEDSPEC Web address for other silt fence design and construction considerations: http://owww.cecer.army.mil/ll/sedspec/design/DisplayMeth.cfm?PKeyMethod=74&FROMUSE=13&PKEYPRACTICE=8 (ref 46).

Straw Bales

- Install bales in a single row, lengthwise, with adjacent bales tightly abutting each other.
- Stake each bale with two stakes driven at least 18 inches into the ground.
- The usable life for straw bale sediment barriers is 3 months. Replace as needed until temporary sediment containment is no longer needed.

TIP:
Refer to the following SEDSPEC Web address for other straw bale sediment barrier design and construction considerations: http://owww.cecer.army.mil/ll/sedspec/design/DisplayMeth.cfm?PKeyMethod=1&FROMUSE=13&PKEYPRACTICE=8 (ref 47).

Brush Barriers

- Construct brush barriers (ref 49) from small trees (6-in. maximum diameter), branches, brush, and other permeable material found on the range.
- Cover the brush with filter fabric to hold the material in place and increase sediment capture efficiency. Secure filter fabric on the drainage side of the barrier.
- Construct the barrier at least 3 feet high and 5 feet wide at the base.

Maintenance Requirements: Temporary sediment barriers must be inspected after each significant rainfall event (>1 in. in a 24-hr period). Sediment should be removed when it reaches one third the height of the barrier or 9 inches (maximum). Damaged or clogged barriers should be repaired immediately.

Cost Elements: Successful temporary sediment barriers that collect sediment suspended in runoff water require adequate storm water management designs by an experienced engineer. The typical cost elements associated with this BMP are presented in Table 3-24. The major factors that can affect the performance and cost of this BMP are improper design for runoff conditions and improper maintenance to maintain the filtering capabilities of the barrier.

TABLE 3-24. SEDIMENT BARRIER COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	Annual Operation and Maintenance		
Surveying	Labor to inspect and maintain sediment barriers	Document maintenance	BMP overhead
Sediment barrier design	Material to repair sediment barriers	Environmental management plan development and maintenance	Range downtime
Planning			
Contracting			
Construction permitting			
NEPA documentation			
Labor to support sediment barrier installation			
Material to support sediment barrier installation			
Equipment rental			

NEPA = National Environmental Policy Act.

Dry Detention Ponds

Description: Dry detention ponds are shallow basins designed to detain storm water runoff to allow suspended sediments time to settle and to drain completely during dry periods. The ponds are drained through risers that release the runoff water at a slow rate (ref 50).

Benefit: Detention ponds offer a cost-effective means of controlling sediment transport from large drainage areas. The design of the ponds can be varied to address site-specific water quality issues. Sediment removal rates may vary widely with detention pond design and the characteristics of the suspended sediment. TSS removal rates of 55 to 100 percent are possible, with an average removal rate of 70 percent based on USEPA sources (ref 51).

Applicability: Detention ponds are widely used in all regions of the United States for storm water and sediment control. They can support drainage of areas 10 to 100 acres and are suitable for areas where other erosion control practices may not support the prevention of off-range sediment transport (ref 50).

Limitations: Detention ponds are not effective in removing soluble metals from runoff. There may be limited area between ranges or down range to install detention ponds because of site topography or range layout. Dry detention ponds generally require a large area, typically 2 to 3 percent of the drainage area. In addition, drainage areas of less than 10 acres can usually be managed more cost-effectively and with fewer maintenance problems by other management methods (ref 50).

Implementation Guidance: Prior to making drainage improvements, the installation environmental office should be consulted to determine local permit and construction guidelines. Dry detention ponds for use in range areas should not be installed without a well-developed design based on an engineering survey and layout. Design considerations are as follows:

- The drainage area that the detention pond supports should be a minimum of 10 acres.

- The maximum slope on which a detention pond should be installed is 15 percent.

- If soils are highly permeable, an impermeable liner should be installed to limit infiltration to groundwater or sinkhole formation.

- The base of the dry detention pond should be a minimum of 2 feet above the seasonally high groundwater table.

- Dry detention ponds should have a length to width ratio of 1.5 to 1 (minimum) to allow maximum flow path and detention time within the pond. The pond volume should be detained for between 12 and 48 hours for effective sediment settling to occur (ref 50).

- Inlets and outlets of the pond should be designed to provide low flow rates and stabilized to prevent erosion.

- Overflow outlets should be included in the dry detention pond design to prevent overflow of the pond if the pond outlet becomes clogged or if flow volumes exceed the design flow.

Maintenance Requirements: Typical maintenance activities and schedule for dry detention ponds are provided in Table 3-25.

TABLE 3-25. DRY DETENTION POND MAINTENANCE SCHEDULE[a]

Activity	Schedule
• Note erosion of pond banks or bottom; repair eroded areas.	Semiannual inspection
• Inspect for damage to the embankment • Monitor for sediment accumulation • Examine to ensure that inlet and outlet devices are free of debris and operational	Annual inspection
• Mow side slopes • Manage soil nutrients • Remove litter and debris	Standard maintenance (as needed)
• Seed or sod to restore dead or damaged ground cover	Annual maintenance (as needed)
• Remove sediment from the forebay	5- to 7-yr maintenance
• Monitor sediment accumulations, and remove sediment when the pond volume has been reduced by 25%	25- to 50-yr maintenance

[a]Modified from Reference 50. (Source: USEPA, 2004)

Cost Elements: Successful detention ponds that decrease runoff velocity and remove suspended solids from the runoff require adequate storm water management designs by an experienced engineer. The typical cost elements associated with this BMP are presented in Table 3-26. The major factors that can affect the performance and cost of this BMP are improper design for runoff conditions and improper maintenance.

TABLE 3-26. DRY DETENTION POND COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
BMP equipment purchase	Labor to operate and maintain BMP	Document maintenance	BMP overhead
Surveying	Labor to manage hazardous waste	Environmental management plan development and maintenance	Range downtime
BMP design	Utilities	Reporting requirements	BMP equipment replacement
Planning	Hazardous waste disposal fees	Waste test/analyses	Demobilization or disposal at end of BMP useful life
Contracting	Management of recyclable material	Waste transportation (on- and off-range)	
Construction permitting	Consumable materials	Safety training (if required)	
Labor for BMP installation	Ongoing training of O&M personnel (if required)		
Material for BMP installation			
Equipment rental			
Training of O&M personnel (if required)			
NEPA documentation			

NEPA = National Environmental Policy Act.
O&M = Operation and maintenance.

Sand Filters

Description: Sand filters are used to control storm water runoff quality. A typical sand filter consists of two or three chambers. One of the sand filter designs commonly used for commercial development and parking area runoff is shown in Figure 3-23. The heavy sediments settle in the first chamber. The second chamber is a filtration chamber where runoff water filters through a sand bed to remove remaining suspended solids. The third chamber is a discharge chamber, which may be incorporated into the design of the second chamber in some sand filter designs (fig. 3-23). Total metals removal efficiency for this type of filter is considered moderate if a significant portion of the metals are in the dissolved-phase (ref 52). In most cases, dissolved-phase lead in storm water runoff is not a significant issue; however, in situations in which dissolved-phase lead must be addressed in addition to the suspended lead, filtration performance may be improved with the addition of a reactive medium to the sand filter that will precipitate or bind the dissolved portion of the lead.

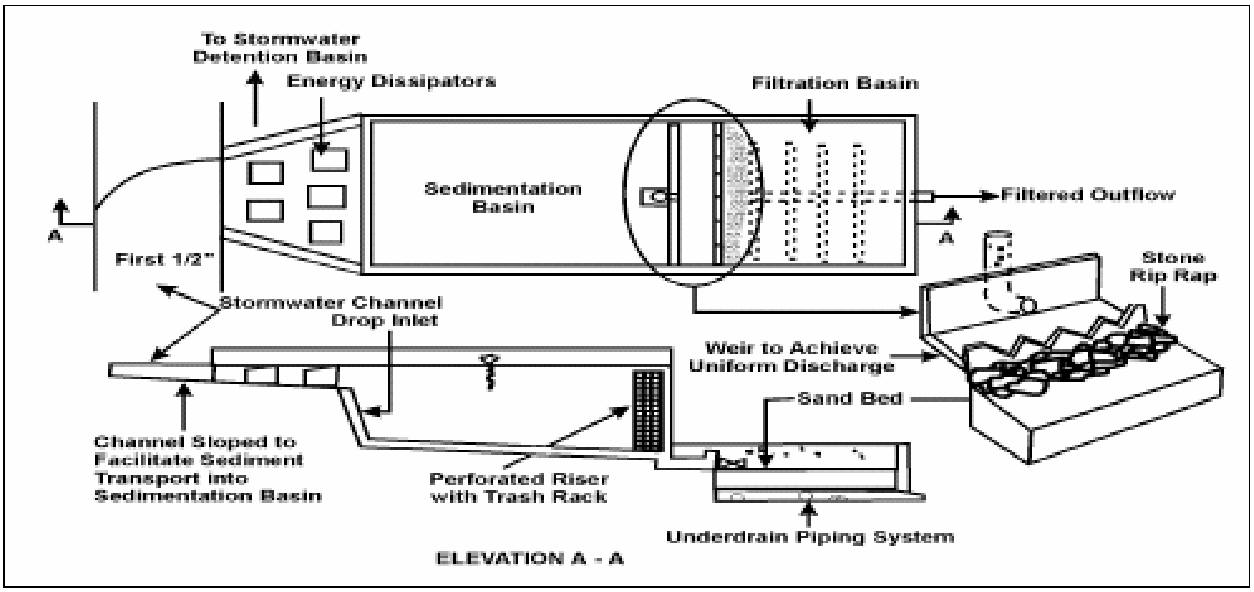


Figure 3-23. Typical Austin sand filter design.
(Source: USEPA, 1999)

Benefit: Sand filters can be a highly effective BMP for removal of suspended solids in runoff from relatively small range drainage areas (<10 acres). The addition of organic, alkaline, or reactive media to the sand filter may also result in effective removal of dissolved lead from storm water runoff.

Applicability: Sand filters may be applicable to range drainage areas that are too small (<10 acres) for dry detention ponds to be implemented effectively. They may be able to effectively manage storm water runoff quality from hot spots (backstop berms and other areas of high metals concentration) on the range.

Limitations: The size and characteristics of the drainage area will influence the effectiveness of the sand filter. Heavy sediment loads in the runoff will quickly clog the system, thus requiring frequent maintenance. In addition, in colder climates the filter system may not be operable because of frozen filter media and drainage pipes. Vegetation debris (leaves, straw, grass cuttings, etc.) may frequently clog the filter.

Implementation Guidance: Prior to making drainage improvements, the installation's environmental office should be contacted to determine local permit and construction guidelines. Sand filters for use in range areas should not be installed without a well-developed design based on an engineering survey and layout. Design considerations are as follows:

- The drainage area that the sand filter supports should be less than 10 acres.
- The location of the sand filter should have a sufficient slope to allow a 5-foot minimum head between the inlet and the outlet of the system. This head is required for gravity flow through the system.
- A 2-foot minimum separation should be between the bottom of the sand filter and the seasonally high groundwater table to prevent damage to the structure and possible contamination of the groundwater.
- Grass filter strips are recommended to be installed upstream of the sand filter as a preliminary sediment management method to prevent the rapid buildup of sediment in the sand filter.
- The size of the sedimentation chamber and filter bed must be designed based on the calculated volume of drainage area runoff water expected to be managed by the system, required retention time, and permeability of the filter media to effectively remove the metals munitions constituents to acceptable levels. The acceptable munitions constituent levels should be based on the evaluation criteria that was used to determine the need for storm water BMPs. General design guidance for selected filter designs are discussed in References 51 and 52.
- The filter media type and depth should be based on the runoff characteristics. Generally, medium grade sand is selected to filter suspended solids. If additional filtration is required to address dissolved-phase metals, then a treatability study should be performed to identify the most efficient media amendments.
- The outlet of the sand filter should be designed to provide low flow rates and stabilized to prevent erosion.
- An overflow bypass should be included in the sand filter design to prevent overflow of the filter if the filter media becomes clogged or if flow volumes exceed the design flow.

Maintenance Requirements: Frequent inspections and maintenance are required to maintain sand filter systems. Typical maintenance activities and frequencies are presented in Table 3-27.

TABLE 3-27. TYPICAL SAND FILTER MAINTENANCE REQUIREMENTS[a]

Activity	Schedule
• Ensure that contributing area and filter inlets and outlets are clear of debris. • Ensure that the contributing area is stabilized and mowed with clippings removed. • Ensure that the filter surface is not clogging (also after moderate and major storms).	Monthly
• Ensure that the filter bed is clean of sediment and the sediment chamber is no more than half full of sediment. Remove sediment if necessary. • Confirm that there is no evidence of deterioration or cracking of concrete. • Inspect inlets, outlets, and overflow spillway to ensure good condition and no evidence of erosion. • Repair or replace any damaged structural parts. • Stabilize any eroded areas. • Ensure that flow is not bypassing the filter.	Annual

[a]Modified from Reference 53. (Source: USEPA, 2004)

Cost Elements: Successful sand filters that remove suspended solids and lead munitions constituents from the runoff require storm water management designs by an experienced engineer. The typical cost elements associated with this BMP are presented in Table 3-28. The major factors that can affect the performance and cost of this BMP are improper design for runoff conditions and improper maintenance.

TABLE 3-28. SAND FILTER COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Sand filter equipment purchase	Labor to inspect and maintain BMP	Document maintenance	BMP overhead
Surveying	Labor to manage hazardous waste (spent filter media)	Environmental management plan development and maintenance	Range downtime
Sand filter design	Hazardous waste disposal fees	Reporting requirements	Demobilization or disposal at end of sand filter's useful life
Planning	Consumable materials (replacement filter media)	Waste test/analyses	
Contracting	Ongoing training of O&M personnel (if required)	Waste transportation (on- and off-range)	
Construction permitting		Safety training (if required)	
Labor to support sand filter installation			
Material to support sand filter installation			
Equipment rental			
Training of O&M personnel (if required)			
NEPA documentation			

NEPA = National Environmental Policy Act.
O&M = Operation and maintenance.

Dust Control

Description: Dust control measures provide a means of controlling dust generated in areas disturbed by small arms round impacts and range maintenance activities that create soil disturbances (e.g., berm repair, grading). Common dust control measures include sprinkling/ irrigation, vegetative cover, mulch, windbreaks, and dust palliatives.

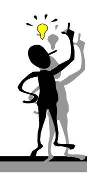
Benefit: Dust control measures reduce the surface and air transport of dust and metal munitions constituents during training activities and range maintenance. Dust control measures also reduce the potential for metals munitions constituent exposure to the range user and maintenance personnel.

Applicability: Dust control measures are applicable to any range maintenance activity or small arms range use that results in the generation of dust from disturbed areas. These measures may be particularly applicable to arid or semiarid range areas where soil is dry and subject to aerial transport.

Limitations: Some dust control measures are temporary and require reapplication on a regular basis, which increases the cost of range use and maintenance activities. In addition, excessive use of some chemical dust palliatives may cause surface or groundwater contamination. Some dust control measures (windbreaks) require land space that may not be available (ref 54).

Implementation Guidance: Dust control measures may be either temporary or permanent. Permanent controls are needed to reduce dust problems resulting from small arms range use. Permanent measures include vegetative cover and windbreaks. Vegetative cover provides a low-cost means of shielding bare soil from wind erosion. The vegetative cover BMP in this manual may be consulted for establishment guidance. Windbreaks (trees) planted along the boundary of the range can also provide a low-cost means of controlling off-range transport of dust. For each vertical foot of height, an 8- to 10-foot deposition zone (ref 55) develops on the leeward side of the windbreak. The trees in a windbreak should be densely planted to reduce permeability through the windbreak. VegSpec can be used to provide guidance for tree selection and planting guidance.

TIP:
The VegSpec program is online at: http://ironwood.itc.nrcs.usda.gov/Netdynamics/Vegspec/pages/HomeVegspec.htm.



Temporary dust control measures include sprinkling/irrigation, mulch application, and application of dust palliatives. Sprinkling/irrigation is an inexpensive dust control measure commonly used during earthmoving operations. This means of dust control should be used during range maintenance activities, if available. Mulch can be used as a ground cover similar to vegetation and has been proven to reduce wind erosion by up to 80 percent (ref 55). The effectiveness of chemical dust palliatives range from 70 to 90 percent (ref 55) based on limited research. These palliatives can be of many forms (asphalt emulsions, latex emulsions, resin in water, etc.). They are usually sprayed on the soil prior to performing the dust generating activities. If used, consideration should be taken as to whether the chemical is biodegradable or water-soluble and what effect it may have on the environment (ref 55). These measures are recommended to support dust producing range maintenance activities. Generally, these methods are too expensive for use as a range operation dust control measure, but if vegetation cannot be established to mitigate wind erosion and transport, then these options should be considered.

Maintenance Requirements: Vegetative dust control measures should follow the maintenance requirements identified in the sustainment of vegetative cover BMP. Temporary dust control measures will require periodic renewal or reapplication. The frequency of this reapplication depends on the type of control measure used and the site conditions on which it is used. Dust control measures should be inspected quarterly as a minimum and maintained as required.

Cost Elements: The typical cost elements associated with this BMP are presented in Table 3-29. The major factor that can affect the performance and cost of this BMP is improper maintenance.

TABLE 3-29. DUST CONTROL COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Planning	Labor to inspect and maintain the dust control effectiveness	Document maintenance	BMP overhead
Contracting	Materials needed to replenish the dust control measure	Environmental management plan development and maintenance	Range downtime
Labor to support dust control installation	Ongoing training of O&M personnel (if required)	Safety training (if required)	
Material to support dust control installation			
Equipment rental			
Training of O&M personnel (if required)			

O&M = Operation and maintenance.

3.2.4 Berm Design and Structural Enhancements

Berms that serve as backstops on small arms ranges are primary collection points for small arms metal constituents on the range. These berms must be actively managed to prevent transport of lead and other small arms related metals from these source zones. Berm designs, maintenance, and in some cases simple structural enhancements can be implemented to manage these areas. These methods are designed to address lead transport through erosion and storm water runoff. Berm design and structural enhancements to impact berms can be used to provide an inherent stability to the slope of the berm and the concentrated impact points. Steep berm slopes naturally erode excessively. This erosion is accelerated by the soil disturbance caused by the impact of the rounds on the berm. In addition, the establishment of vegetation on berms with steep slopes is extremely difficult. The BMPs in this section will identify methods of enhancing the structure and stability of the backstop berms. Some of these BMPs may also be applied to berms that are installed to protect range targetry, but in most cases compliance with current USACE design guidance should be sufficient to provide a stable berm for target protection. The BMPs presented in this section include

- berm design and
- berm structural enhancements.

Berm Design

Description: The design of backstop berms has a significant impact on their ability to retain the small arms round metals within the berms. Berms with steep slopes are not stable. Erosion is a constant problem in general, and the soil disturbance caused by range use on steeply sloped berms exacerbates the erosion of the soil from areas on the berm that contain high lead concentration. Designing berms with inherently stable slopes will minimize the potential for lead transport from the range by mitigating the load-carrying capacity of erosion and storm water runoff sediment (fig. 3-24).

Figure 3-24. Berm slope grading.

Benefit: Berms with stable slopes will minimize the potential for lead transport from the range. Establishing a stable slope will promote a low-velocity sheet flow on the berm, which will reduce the potential for rill and gulley development and reduce the sediment load-carrying capacity of the runoff. In addition, on berms with stable slopes, it will be easier to establish vegetation, which will further inhibit erosion and storm water runoff problems. Increased slope stability will also reduce the maintenance frequency necessary to maintain the berm.

Applicability: Stable berm designs are particularly effective on impact berms located behind fixed targets, as are often found on 25-meter ranges (FCC 17801). These berm designs may also be applied on any other range type where berms are required to capture rounds or protect equipment and personnel.

Limitations: A concern with reducing berm slope is the slightly increased potential for the rounds to skip over the berm; however, this would not impact the SDZ for the range. Reducing the slope of the berm will require more soil to construct the berm and a larger area on which to locate the berm. Space limitations or fill dirt availability may be issues at some installations.

Implementation Guidance: The overall objective of implementing an improved berm design is to improve the containment of the lead in or immediately around the berm. This is achieved by designing the berm to manage erosion and storm water runoff. The most effective means of accomplishing this is to reduce the slope of the berm to a slope that is inherently stable for the soils used to construct the berm. This slope may vary slightly depending on the soil characteristics, but a 2:1 slope (approximately 26^{o} from horizontal) generally produces an inherently stable berm for most soil types. Berm thickness should be designed to contain the largest caliber of ammunition expected to be fired on the range. DA PAM 385-63 Range Safety, Chapter 6, Table 6-1 Minimum Thickness of Material for Positive Protection Against Caliber Ammunition Listed provides minimum thickness requirements for the berm core (ref 56). On a cross-sectional view, the berm core would be a rectangular shape, forming the top of the berm and center of the base of the berm. Determine the height of the berm by applying an error factor of 8 degrees above the line-of-fire from the position of firer to the target. The establishment of vegetation on the berm should be implemented in conjunction with the reduced berm slope. The vegetation will further enhance berm stability by stabilizing the soil around the major impact points on the berm. This stability will minimize the erosive effects of storm water runoff on the disturbed areas of the berm.

Maintenance Requirements: The berms should be inspected annually and after major storm events for indications of erosion (rill and gulley formation). Inspections should be conducted more frequently while vegetation is being established, because the berms are more susceptible to erosion during this period. The overall berm slope should remain stable at a maximum 2:1 slope, so complete regrading of the berm surface should not be required as a maintenance activity and in fact should not be performed because it would destroy any vegetation established on the berm. Instead, maintenance activities should be restricted to filling in the disturbed bullet pocket or bullet wear areas on the berm. Depending on range use, this type of maintenance may be required once every 3 to 5 years. Maintenance for vegetation should be performed as specified in the vegetation establishment and sustainment BMP.

Cost Elements: The typical cost elements associated with this BMP are presented in Table 3-30. The major factors that can affect the performance and cost of this BMP are improper design for runoff and soil conditions and improper maintenance.

TABLE 3-30. BERM DESIGN COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Surveying	Labor to inspect and maintain the berm	Document maintenance	BMP overhead
Berm design	Fill dirt to replenish worn areas on the berm. (See vegetation maintenance BMP for additional berm requirements.)	Environmental management plan development and maintenance	Range downtime
Planning		Safety training (if required)	Demobilization or disposal at end of BMP useful life
Contracting			
Construction permitting			
NEPA documentation			
Labor to support berm modification			
Material to support berm modification			
Equipment rental			

NEPA = National Environmental Policy Act.

Berm Structural Enhancements

Description: Structural enhancements to the berm focus on stabilizing the area around the concentrated impact points (bullet pockets) on the berm (fig. 3-25). The structural enhancements consist of easily fabricated, low-cost structures that (coupled with vegetation) prevent the bullet pocket from indefinitely increasing in size as a result of erosion. These structures are intended to be used as an enhancement of the 2:1 slope berm design identified in the previous BMP. They are not intended as an alternative to construction of a berm with a stable slope.

Figure 3-25. Typical 25-meter range impact berm and bullet pockets.

Benefit: Structurally enhancing the berm face around the soil disturbed by small arms use can limit the potential for erosion and sediment transport from these areas. The increased stability in these areas can also further reduce maintenance requirements in these disturbed areas.

Applicability: Berm structural enhancements are particularly effective on impact berms located behind fixed targets, as are often found on 25-meter ranges (FCC 17801). They also may be effective on berms on other range types where a well-defined shot pattern exists.

Limitations: These structures can only be used on berms that have a well-defined wear patterns from small arms firing. If these wear patterns change as a result of changes in how training is conducted on the range, movement (or modification) of targets, and so forth, then the structures may be damaged or destroyed. These structures are generally not applicable to ranges where small arms fire is widely distributed on the berm.

Implementation Guidance: Structural enhancement of the bullet pocket will help mitigate erosion and soil loss from the berm. If needed, this type of structural enhancement should be implemented simultaneously with berm vegetative efforts to stabilize the berm. Bullet pocket structural enhancements consist of providing limited weather protection or structural support over the impact point on the berm. They provide stability by preventing runoff water from eroding the hole formed by the impact of the rounds on the berm. The size of the structures will be site-specific and will vary with the spread of fire on each firing lane. Typically, the larger the impact area on the berm, the less effective and more costly the structural enhancements will be. The structures may be fabricated from wood or from a nonricocheting material such as shock-absorbing concrete. Generic design parameters for each type of bullet pocket structural enhancement are discussed below.

Erosion Control Mat Bullet Pocket Cover

This erosion control mat bullet pocket cover simply uses a permeable erosion control fabric (landscape fabric, jute net, etc.) to cover the area where the bullet pocket is expected to form. The fabric can be anchored to the ground with u-shaped wire staples or stapled to a simple wooden frame constructed from 2- by 4-inch treated studs (fig. 3-26). The wooden frame size shown in Figure 3-26 is the typical area in which the majority of rounds fired at a single silhouette target will impact on a berm on a 25-meter range when the berm is located within 5 meters behind the target. The landscape fabric/frame size should be adjusted based on the number of targets used per lane, distance of the berm behind the target line, or round dispersion resulting from the type of training being conducted on the range. The wooden frame with the landscape fabric attached can be anchored to the berm by digging a shallow trench in which the frame will be inserted. Rounds fired at the targets will penetrate the landscape fabric and enter the berm. The landscape fabric will minimize the erosion caused by the impact of raindrops in the disturbed soils of the bullet pocket, and improve the retention of bullet debris within the bullet pocket by mitigating the soil splatter occurring when the rounds impact the berm.

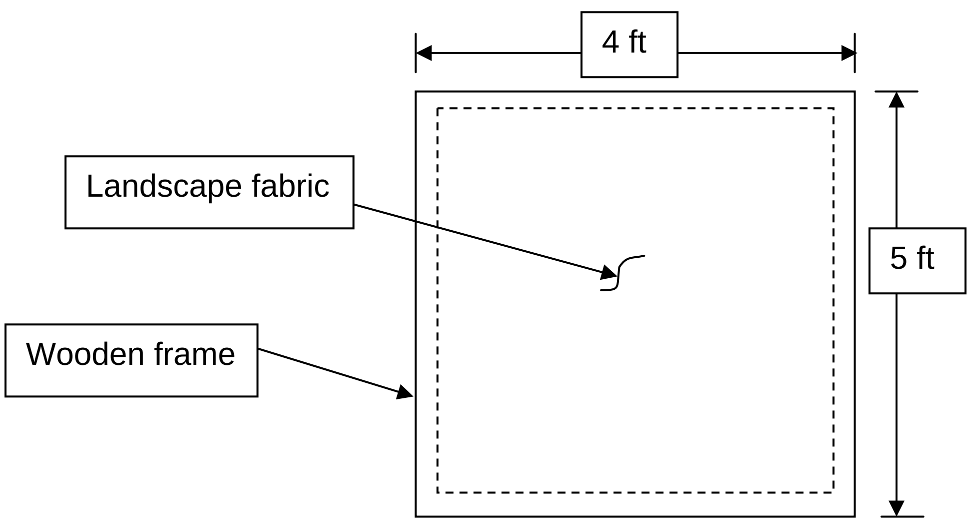


Figure 3-26. Landscape fabric wooden frame.

Buried Structural Support

The buried structural support is a 2-foot, 6-inch by 5-foot frame constructed from treated 2- by 4-inch studs with a 3/4-inch plywood top (fig. 3-27). The buried structural support is covered with a vinyl/rubber cover to provide a moisture barrier between the plywood and the soil. The vinyl/rubber cover is attached with 9/16-inch staples. The buried support is buried in the berm immediately above the area where the bullet pocket is expected to form and is expected to provide structural support to the berm above the bullet pocket. This would minimize the slumping of the soil above the bullet pocket into the shot-out area that would accelerate the erosion in this area. The structural support also provides a moisture barrier for the bullet debris within the bullet pocket from precipitation that infiltrates the soil above the bullet pocket area. This may provide some reduction in potential leaching of lead through the soil column.

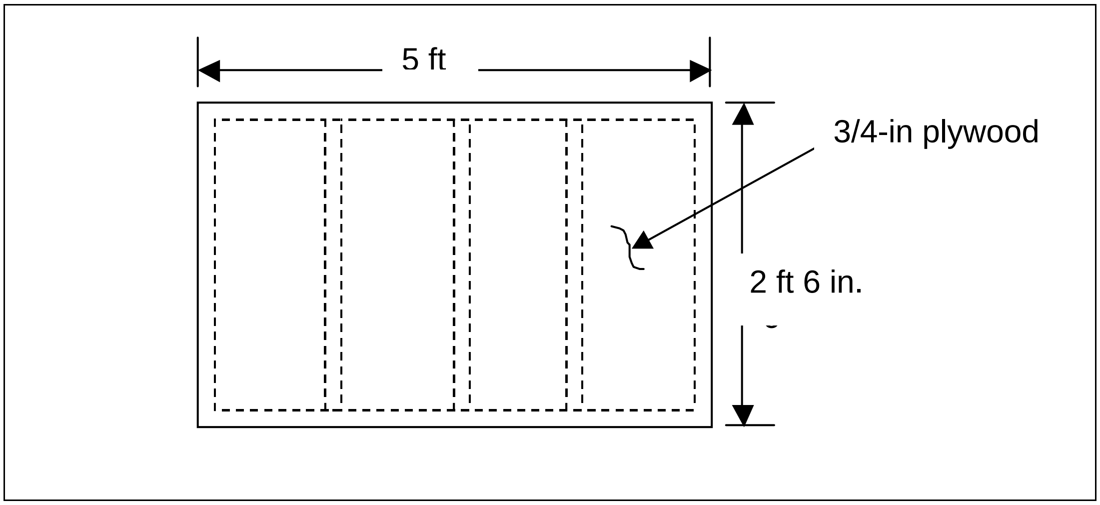


Figure 3-27. Buried structural support.

Bullet Pocket Roof/Buried Structural Support

The roof/buried structural support is a 4- by 8-foot frame constructed from 2- by 4-inch treated studs with a 3/4-inch plywood top (fig. 3-28). The roof/buried structural support is covered with a vinyl or rubber cover to provide a moisture barrier between the plywood and the soil/precipitation. The vinyl/rubber cover is attached with 9/16-inch staples. The roof/buried structural support is installed immediately above the area where the bullet pocket is expected to form. The front end of the structure is supported by a 4- by 4-inch treated post at each corner. The back end of the structure is buried approximately 2 feet into the berm. The roof is angled slightly to promote water drainage back toward the berm. This structure is expected to provide structural support to the berm above the bullet pocket and weather protection to the bullet pocket. This would minimize the slumping of the soil above the bullet pocket into the shot-out area that would accelerate the erosion in this area. The roof/buried structural support is also expected to mitigate the erosive effects of precipitation directly on the bullet pocket as well as provide some reduction in potential leaching of lead through the soil column.

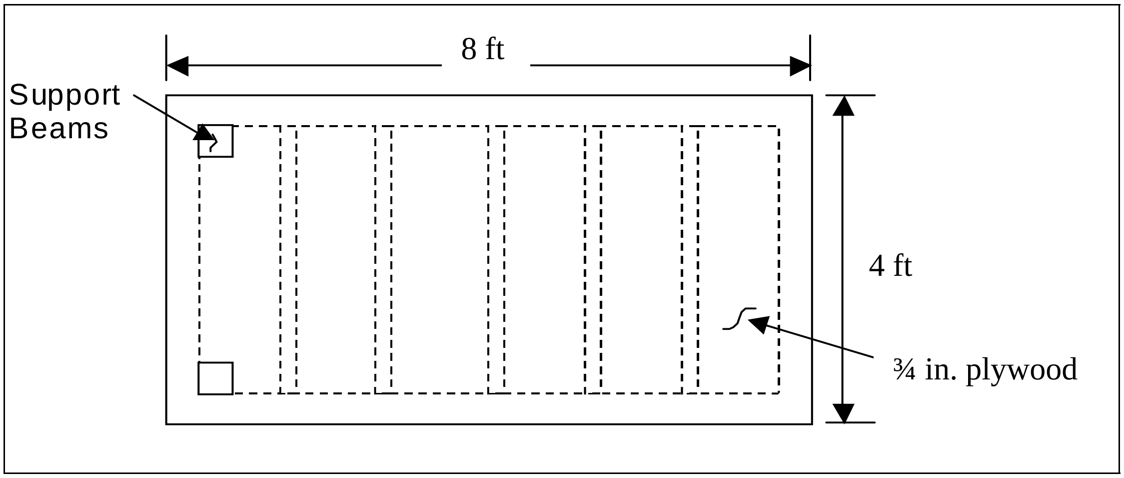


Figure 3-28. Roof/buried structural support.

Maintenance Requirements: The structural enhancements should be inspected quarterly for damage. Inspections should be conducted more frequently when first installed to ensure that the structures have been positioned properly on the berm. Maintenance activities should primarily consist of repairing or replacing the landscape liner when holes large enough to allow soil movement have developed. In addition, structural repairs may be needed to repair bullet damage caused by stray rounds. Depending on range use and proper placement of the structures on the berm, structural repairs may be required once every 3 to 5 years.

Cost Elements: The typical cost elements associated with this BMP are presented in Table 3-31. The major factors that can affect the performance and cost of this BMP are improper design and installation with respect to the bullet impact patterns on the berm and improper maintenance.

TABLE 3-31. BERM STRUCTURAL ENHANCEMENT COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Structural enhancement design	Labor to inspect and maintain the structures	Safety training (if required)	BMP overhead
Planning	Material to repair the structures		Range downtime
Contracting			
Labor to support structure fabrication and installation			
Material to support structure fabrication and installation			
Equipment rental			

3.2.5 Geosynthetic Materials

Geosynthetic materials are used in a wide range of applications, such as general land management and rehabilitation, sediment and erosion control, and storm water management and containment. The uses of geosynthetic materials on small arms ranges for land rehabilitation, sediment and erosion control, and storm water management have been discussed in other BMPs in this manual. This BMP section will focus on geosynthetic material use as an impermeable liner within a subsurface leachate containment system. These liners may be used underneath storm water drainage channels or detention ponds, as discussed in the storm water management section (para 3.2.3). They may also be used to contain mobilized metals in the unsaturated zone beneath the impact berm or other predominant impact points on a range. In these cases, the geosynthetic material acts as a physical barrier between water infiltration and groundwater. Geosynthetic materials used for this purpose are available in a wide range of material types, compositions, and physical properties.

The decision to contain subsurface lead transport on ranges should be coordinated with the installation environmental management. The use of liners will require drainage systems to manage the water that collects above the liner. The water collected and subsequently discharged may require treatment for lead munitions constituents and may require controls on the discharge. This method of controlling subsurface lead migration on ranges is very expensive and will result in significant range downtime during installation. It should be considered a lead management method of last resort and should be proposed only when other lead migration and pollution prevention methods have been exhausted.

Geosynthetic Liner Systems

Description: Geosynthetics are produced from a wide range of base polymers (e.g., polyester, polyethylene, and polypropylene) that are flexible, strong, lightweight, and durable (ref 57). They have been adapted to perform many functions, one of which is containment. Geosynthetic containment products primarily include geomembranes and geosynthetic clay liners (ref 57). A geosynthetic liner system may consist of a number of layers of liner material with a leachate collection and treatment system incorporated into the design. The specific design and use of geosynthetic liner systems will be site-specific and may be influenced by regulatory requirements. The factors affecting liner design may include the soil physical and chemical characteristics, depth to groundwater, lead physical and chemical characteristics, and subsurface stability.

Benefit: Liners provide a means of controlling the subsurface dispersion of lead, thus minimizing the impact of small arms range use on the groundwater.

Applicability: Liner use is applicable anywhere that small arms round metal constituents are accumulated and subsurface migration of dissolved lead to groundwater has the potential to occur. A liner system may be applied when other lead migration or pollution prevention methods cannot effectively control the subsurface migration of the metals.

Limitations: Liner installation and leachate treatment is very expensive and will result in significant range downtime during the liner installation. In addition, this method of controlling subsurface metals migration has not been demonstrated in a range application. Not all design and performance issues specific to a range applications have been thoroughly addressed.

Implementation Guidance: Prior to installing a liner system under a berm or other area of concentrated metals buildup, the installation's environmental office should be consulted to determine regulatory permitting and construction requirements. Containment liner systems should not be installed without a well-developed design based on an engineering survey and layout.

In general, liner systems for small arms range applications should have a simple design unless otherwise dictated by site-specific regulatory issues. Two basic liner designs may be applied to a range area. The liner system may incorporate a reactive media layer to precipitate dissolved lead prior to leachate collection and discharge, or the liner system may simply collect leachate from the area and discharge it to an external leachate treatment system. Each of these system designs is described below. (Note: Neither of these system designs has been field tested in range applications. As a result, the use of this BMP involves some risk since design and performance issues specific to range applications have not been investigated.)

Liner Systems with Reactive Media

A typical liner system design that incorporates a reactive media layer is shown in Figure 3-29. The liner design is similar in design and function to that of a dry swale with the exception that the system is buried beneath the primary impact points on the range. The liner system incorporates a reactive media layer with a French drain-type design in the bottom. Underneath the reactive media/drainage system is the geomembrane or geosynthetic clay liner. The liner serves as an impermeable barrier that prevents further infiltration of water and metals. In this design, the water that infiltrates the soil passes through the filtering media and into the gravel layer that encases the perforated pipe. The leachate from this pipe may discharge the water into a storm water management feature such as a detention pond or to other areas on the range. Design considerations for small arms range use of liner systems with reactive media are as follows:

- Soil permeability and dissolved-phase lead transport should be characterized prior to designing and installing a liner system. These data will not only verify the need for a containment system, they will also establish some of the design parameters for the system.

- The bottom of the liner system should be a minimum of 2 feet above the seasonally high groundwater table.

- The liner material should be a minimum of 3 feet below the surface to ensure that small arms rounds will not penetrate the liner.

- The liner system design should ensure that the liner material (geomembrane or geosynthetic clay liner) will be installed with as little physical stress on it as possible. These liner materials are not designed to support a physical load; they are barrier materials that are supported by the soils underneath them. The physical characteristics of the underlying soils must be characterized to ensure that they will adequately support the liner material and the load that will be placed above the liner. If the underlying soil settles or a sinkhole develops, then the liner material may fail when stressed by the load above (ref 58).

- The leachate should not be discharged directly into a surface water resource.

- The reactive media layer in the liner system may consist of an alkaline material (i.e., limestone) or a reactive material (e.g., phosphate, sulfide, carbonate) that facilitates the precipitation of the lead ions by means of either a pH shift in the leachate or by reacting with the lead ions to form relatively stable lead species. The amount of alkaline or reactive material to mix into the reactive media layer will be dependent on the dissolved lead concentrations in the leachate and the infiltration volume, rates, and area.

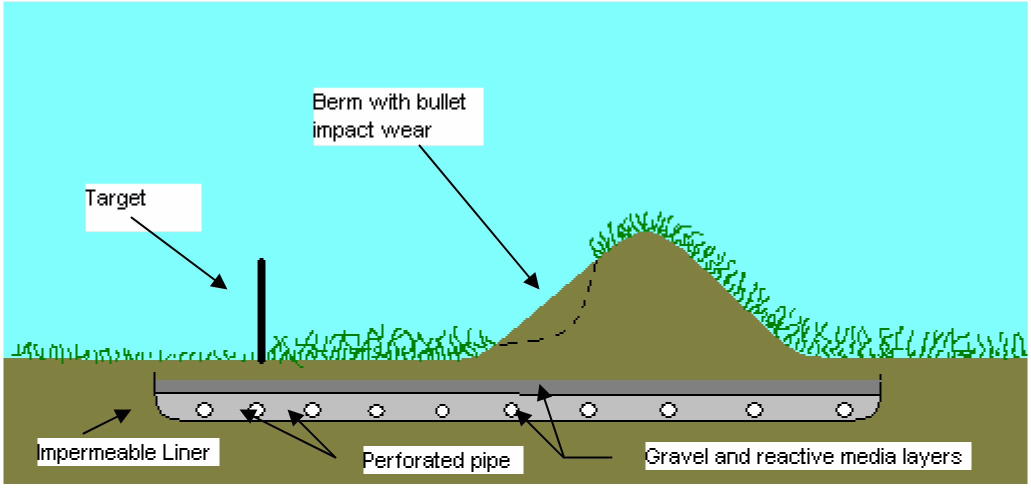


Figure 3-29. Geosynthetic liner system with reactive media layer.

The long-term performance of the liner system that incorporates a reactive filter media is not known. Over time, the alkaline or reactive materials may deplete and require replacement. In addition, mixing in too much of the alkaline or reactive material may create adverse water quality issues such as elevated discharge water pH or elevated nutrient content. Care must be taken in the selection of the appropriate type of reactive materials, because some forms of the material may go into solution faster than other forms. This, too, could result in elevated nutrient levels in the discharge water. Issues with the use of reactive materials to control dissolved-phase lead are discussed in the soil amendments section (para 3.2.6). The concerns expressed there also apply to the application of the soil amendments to the liner system reactive media.

Liner Systems with External Leachate Treatment Systems

A typical liner system design incorporating an external leachate treatment system is shown in Figure 3-30. The liner design is similar in design and function to that of a liner system with reactive media with the exception that no reactive media layer is present. The liner system includes a French drain-type design in the bottom with the geomembrane or geosynthetic clay liner installed underneath the drainage system. The liner serves as an impermeable barrier that prevents further infiltration of water and metals. In this design, the water that infiltrates the soil passes into the gravel layer that encases the perforated pipe. The leachate from this pipe discharges to an external treatment system that filters the water to remove any suspended or dissolved-phase lead. This treatment system then discharges the water into a storm water management feature such as a detention pond or to other areas on the range. Design considerations for small arms range use of this type of liner systems are essentially the same as those for the liner systems with reactive media, with the exception that a reactive media layer is not used. The external treatment system design considerations are as follows:

- The external treatment system may consist of a sand filter that removes any remaining suspended solids and an organic, alkaline, or reactive media that removes the dissolved lead. As previously discussed, the alkaline material (i.e., limestone) or a reactive material (e.g., phosphate, sulfide, carbonate) facilitates the precipitation of the lead ions by means of either a pH shift in the leachate or by reacting with the lead ions to form relatively stable lead species. Organic materials or ion exchange resins bind the lead ions to the media, thus removing them from the water. The treatment system will be dependent on the dissolved lead concentrations in the leachate and the volume and flow rates of the leachate.

- External treatment systems should be located in easily accessible areas where maintenance access will not impede the use of the range.

- Clean-out access ports should be incorporated into the design of the discharge lines from the liner system to allow periodic removal of drainage line clogs.

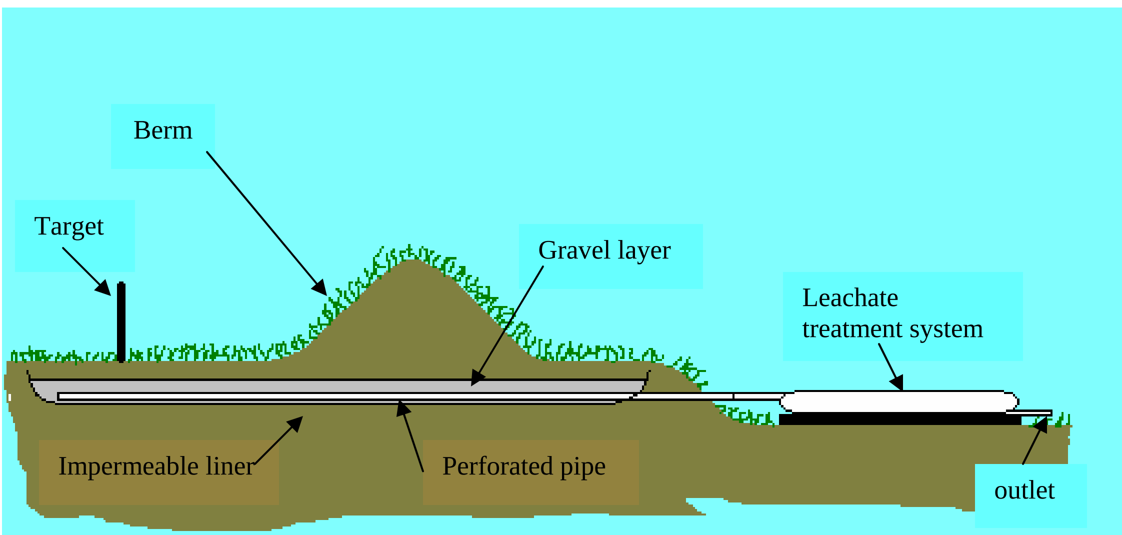


Figure 3-30. Geosynthetic liner system with external treatment system.

Maintenance Requirements: Liner systems with reactive media incorporated in the liner design should be inspected after major storm events. The inspection should consist of ensuring that leachate is draining from the discharge pipe and collecting and analyzing discharge samples to ensure that metals concentrations in the leachate meet target levels established by the installation.

The area under which the liner is installed should be inspected annually to ensure that erosion is not removing the overlying soil layer. Soil should be replaced as required to ensure that the liner will be protected from small arms rounds damage. Typical maintenance activities and frequencies for external treatment systems are presented in Table 3-32.

TABLE 3-32. TYPICAL EXTERNAL TREATMENT SYSTEM MAINTENANCE REQUIREMENTS

Activity	Schedule
• Ensure that leachate flow through the system is not impeded by clogged lines or filter media.	After major storm events
• Ensure that the filter bed is clean of sediment and the sediment chamber is no more than half full of sediment. Remove sediment if necessary. • Analyze discharge samples to ensure that leachate water quality meets established criteria	Annually

Cost Elements: Development of a successful liner system design to control the subsurface spread of lead munitions constituents requires an experienced engineer. The typical cost elements associated with this BMP are presented in Table 3-33. The major factors that can affect the performance and cost of this BMP are improper design and improper maintenance.

TABLE 3-33. GEOSYNTHETIC LINER SYSTEM COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Liner system equipment purchase	Labor to inspect and maintain the liner system	Document maintenance	BMP overhead
Surveying	Labor to manage hazardous waste	Environmental management plan development and maintenance	Range downtime
Liner system design	Utilities (if required)	Reporting requirements	BMP equipment replacement
Planning	Hazardous waste disposal fees	Waste test/analyses	Demobilization or disposal at end of BMP useful life
Contracting	Management of recyclable material	Waste transportation (on- and off-range)	
Construction permitting	Consumable materials	Safety training (if required)	
Labor to support liner system installation	Ongoing training of O&M personnel (if required)		
Material to support liner system installation			
Equipment rental			
Training of O&M personnel (if required)			
NEPA documentation			

NEPA = National Environmental Policy Act.
O&M = Operation and maintenance.

3.2.6 Soil Amendments

Soil amendments to chemically stabilize soluble lead in the soil pore fluid may be applied to range soils. Amendments such as phosphate, lime, and iron, in theory, can be topically applied either through direct broadcast or spraying in a slurried form on range soils. These chemicals may mitigate the corrosion of the lead in the soil, bind the lead ions in the soil pore water through adsorption, or promote the precipitation of lead ions and the formation of relatively insoluble lead species. Soil amendments could be used in areas where lead in the shallow surface soil provides a source of soluble lead ions to surface or groundwater. At this point, the application guidance and performance of these methods of mitigating lead mobility are at various levels of development. Some soil amendment methods are early in the development stage; others have been demonstrated in large-scale field tests with varying levels of success. Some of the soil amendments that have seen significant study and development for lead stabilization will be discussed in this section. Their current performance status and concerns about their use will be identified in the following BMP descriptions. The soil amendment BMPs presented in this section include

- lime amendments and
- phosphate amendments.

Lime Amendments

Description: Lime in the form of oxides, hydroxides, or carbonate has long been used in the agricultural industry to maintain optimal soil pH for crop production. Liming materials are most effective at neutralizing soil acidity when they are thoroughly incorporated and mixed with the soil. Lime addition to establish a neutral pH is believed to have a stabilizing effect on lead in the soil. Corrosion of particulate lead is believed to be inhibited in neutral pH soils, and soluble lead species in soil pore water are expected to precipitate or adsorb to soil particles. Theoretically, soil pH adjustment should provide these benefits; however, the actual benefits of pH adjustment on lead mobility have not been documented. Current studies being conducted by the USAEC are attempting to evaluate the effects pH adjustment have on leachate and storm water runoff lead concentrations. Until actual data is available, the use of lime amendments to adjust soil pH is recommended to support plant growth as opposed to a primary means of controlling lead mobility.

Benefit: Lime addition may provide a low-cost means of minimizing lead mobility within the shallow soil layer (up to 6 in. deep).

Applicability: Lime may be applicable in areas where mixing into the shallow soil layer can occur either through topical application and infiltration or by mechanical mixing (discing). Application to areas of high lead concentration can be achieved if the areas are not dudded. This method may be limited to ranges where only small arms are used and the primary impact points lie primarily in berms or in the immediate vicinity of the targets ((i.e., zero and known distance ranges with berms, Combat Pistol Qualification Course (CPQC) ranges, and 300-meter qualification ranges)).

Limitations: Infiltration of topically applied lime may be limited by soil type and compaction. Mechanical discing to achieve shallow soil neutralization may not be feasible because of training schedules, increased soil erosion caused by the disturbance, existing vegetation establishment efforts, etc. Lime application as a sole means of lead mobility control will probably have a limited effect since the primary means of lead mobility is suspended solids in storm water runoff. Lime application should not interfere with ongoing or prospective erosion control plans and should be focused primarily on providing suitable growing conditions for vegetation establishment and maintenance. A topically applied, no-till application method would be necessary to meet these requirements.

Implementation Guidance: The soil pH should also be determined by collecting representative soil samples from the range for analysis by the local agricultural extension service. The agricultural extension service can recommend the appropriate type of lime, application rates, and mixing alternatives (if required) based on the existing soil type, pH, buffering capacity, and vegetation in the area. Lime application to support vegetation is recommended over lead stabilization purposes alone to ensure that vegetative cover loss and soil erosion are minimized from the range areas.

Maintenance Requirements: Depending on the soil buffering capacity, permeability, and climate, semiannual to annual testing and reapplication may be required to maintain the desired soil pH.

Cost Elements: The typical cost elements associated with this BMP are presented in Table 3-34. The major factors that can affect the performance and cost of this BMP are improper application rates and frequencies.

TABLE 3-34. LIME AMENDMENT COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Sample and analyze soil	Labor to sample soil and apply lime	Document maintenance	BMP overhead
Planning	Soil analyses	Environmental management plan development and maintenance	Range downtime
Contracting	Material (lime)		
NEPA documentation	Equipment rental		
Labor to support lime application			
Material (lime)			
Equipment rental			

NEPA = National Environmental Policy Act.

Phosphate Amendments

Description: Recent laboratory studies and full-scale applications of phosphate amendments have demonstrated that these compounds are effective at fixing dissolved lead through the formation of insoluble species and reducing the ability of lead to leach to groundwater and migrate to surface water. Extensive data have been gathered from previous studies and tests conducted by private industry, academia, and U.S. Army research centers with regards to phosphate compounds for stabilization and immobilization of heavy metals in soil; however, many questions remain concerning the use of phosphate amendments. The long-term stability of the insoluble species has not been thoroughly investigated. Some tests have detected increases in leaching of lead from treated soils after the soil has aged. The cause of the reoccurrence of lead leaching has not been fully investigated and may be due to one or more of a number of factors (e.g., soil chemistry, microbial activity, amendment selection) In addition, depending on the type of phosphate amendment used, as well as the application method, phosphate concentrations in storm water runoff may become an issue. Phosphate-laden storm water runoff has the potential to cause eutrophication effects in surface water resources that may be on or near the range areas. The phosphate concentrations that may cause these effects will vary from site to site and must be determined based on site-specific surface water characteristics. Further research is needed to determine the transport characteristics of the phosphate amendments under different application scenarios to define the appropriate usage parameters and limitations prior to including this means of lead stabilization on operational small arms range soils. Current projects being conducted by the USACE Engineer Research and Development Center - Environmental Laboratory (ERDC-EL) and the Environmental Security Technology Certification Program (ESTCP) are attempting to address some of these issues.

Benefit: When the current concerns with phosphate amendments are addressed, this BMP may provide a low-cost means of minimizing lead mobility within the shallow soil layer (up to 6 in. deep).

Applicability: Like lime, phosphate may be applicable in areas where mixing into the shallow soil layer can occur either through topical application and infiltration or by mechanical mixing (discing). Application to areas of high lead concentration can be achieved if the areas are not dudded. This method may be limited to ranges where only small arms are used and the primary impact points lie primarily in berms or in the immediate vicinity of the targets (i.e., zero and known distance ranges with berms, CPQC ranges, and 300-meter qualification ranges.)

Limitations: Infiltration of topically applied phosphate may be limited by soil type and compaction. Mechanical discing to achieve shallow soil phosphate mixing may not be feasible because of training schedules, increased soil erosion caused by the disturbance, existing vegetation establishment efforts, etc. Phosphate application as a sole means of lead mobility control will probably have a limited effect since the primary means of lead mobility is suspended solids in storm water runoff. Phosphate application should not interfere with ongoing or prospective erosion control plans and should consider the soil requirements for vegetation establishment and maintenance. The concerns identified in the description section above are also a limiting factor. Prior to use of this amendment on active ranges, the concerns identified with phosphate concentrations in storm water runoff, possible eutrophication effects in nearby surface water resources, and reoccurrence of lead leaching should be addressed.

Implementation Guidance: Laboratory testing to determine the appropriate type of phosphate, application rates, and mixing alternatives (if required) based on the existing soil type in the area must be performed by ERDC-EL or companies experienced with in situ stabilization of lead using phosphate based amendments to ensure success. Phosphate application to control lead mobility will be determined by site-specific soil conditions and must be investigated in a treatability study prior to field use.

Maintenance Requirements: Long-term lead stability and reapplication frequency and rates require an ongoing monitoring program to ensure success.

Cost Elements: The application of phosphate to control the subsurface spread of lead munitions constituents requires treatability testing conducted by an experienced engineer or soil scientist familiar with phosphate based lead immobilization methods. The typical cost elements associated with this BMP are presented in Table 3-35. The major factors that can affect the performance and cost of this BMP are improper soil characteristics, proximity to and classification of nearby surface water resources, and improper application rates and frequencies.

TABLE 3-35. PHOSPHATE AMENDMENT COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	**Annual Operation and Maintenance**		
Site-specific treatability testing (may range from $10K to $25K)	Labor to sample and reapply phosphate	Document maintenance	BMP overhead
Planning	Soil analyses	Environmental management plan development and maintenance	Range downtime
Contracting	Material (phosphate amendments)		
NEPA documentation	Equipment rental		
Labor to support application			
Material (phosphate amendments)			
Equipment rental			

NEPA = National Environmental Policy Act.

3.3 Pollution Prevention

Pollution prevention techniques that may be used on small arms ranges include minimizing the amount of lead contained in the round and preventing the rounds from impacting the soil. These techniques should eliminate adverse effects on the environment and reduce future range closure costs for new ranges placed on land on which lead rounds have not been fired. Although these pollution prevention techniques basically eliminate the placement of lead in the environment through either lead replacement or capture, existing small arms ranges will still be faced with legacy lead munitions constituents from past use. The lead placed on the range and impact areas will continue to provide a source of lead for potential environmental transport and effects. This lead source will require management throughout the useful life of the range. In such cases, the economic, and possibly the environmental, benefits of using pollution prevention methods may be greatly reduced or nullified because of the existing munitions constituents. When considering implementation of pollution prevention techniques, specifically the use of bullet traps, on existing ranges or on new ranges being placed on land previously used for small arms training, lead migration prevention methods or lead removal should be considered part of the design and implementation. The costs to include these may greatly increase the cost of using bullet-trapping methods to support environmental compliance on ranges.

Green Ammunition

Description: Green ammunition is being developed under a Department of Defense program to eliminate the use of hazardous materials in small-caliber ammunition manufacturing processes and in the ammunition itself. Tungsten has been selected as the metal to replace lead in the 5.56-mm round. This round is suitable for combat and is expected to reduce environmental compliance burdens on small arms ranges. Other calibers of green ammunition are being developed.

Benefit: Green ammunition may eventually reduce or eliminate the use of small arms rounds containing lead, thus minimizing the impact that small arms training has on the environment.

Applicability: As of the publishing date of this manual, military green ammunition is available only in limited supplies in the 5.56-mm round and may be used on any range that requires this round for training.

Limitations: Until green ammunition is universally developed and accepted for all types of military small arms rounds, currently accepted green ammunition should be targeted for use in areas where other lead management practices cannot effectively mitigate the potential environmental or human health risks that may result from continued training range use. In addition, although the green ammunition program may eventually reduce or eliminate the use of small arms rounds containing lead, lead management practices will be required to be maintained in order to prevent lead from prior range use (legacy lead) from transporting from training range areas.

Implementation Guidance: Green ammunition should be procured when it is accepted and available for use.

Cost Elements: Other than the cost of procuring the green ammunition, no cost elements exist.

Bullet Traps

Description: Bullet traps offer a means of limiting the amount of lead and other small arms rounds metals released to the environment. They have been used in indoor firing ranges for many years. These traps are now commercially available for outdoor applications as a backstop on small arms ranges. Several types of bullet traps are available commercially. The predominant traps that may be applicable to U.S. Army small arms ranges are identified and discussed in this BMP.

Benefit: Bullet traps provide a means of capturing and containing lead fired on small arms ranges. In some cases, the captured rounds may be separated or removed from the bullet trap for recycling.

Applicability: Bullet traps are particularly effective when located behind fixed targets, as are found on 25-meter ranges (FCC 17801). They may be effective as backstops on other range types where a well-defined shot pattern exists. Bullet traps may be considered when total containment of lead is needed on a range because of a high probability of lead migration to surface water or groundwater and when other means of controlling lead mobility are not considered to be effective alternatives.

Limitations: In most cases, the only consideration used when selecting a trap for an outdoor range is whether the trap will stop the round. Naturally, this very important performance characteristic must be satisfied for the trap to be used on a range, but it is not the only performance parameter that must be met. The damage or wear on the trap produced by military rounds, which can be significantly different from commercial rounds, can greatly increase the maintenance frequency and cost of operating a bullet trap. Use of a bullet trap on a range may limit the types of training or munitions used on the range because bullet traps are designed to accept a certain range or type of ammunition. Varying from its designed use may result in damage to the trap. Often, very important environmental and occupational health issues are overlooked. These issues can limit the use of the trap, result in lead exposure to maintenance personnel, and in some cases generate a more mobile lead form than shooting into the soil, thus increasing the environmental risk to the range. In addition, debris generated from the use of some bullet traps may require handling as a hazardous waste when removed from the range.

Implementation Guidance: Prior to selecting a bullet trap, less expensive alternatives should be investigated (e.g., establishing vegetative cover and designing berms to reduce erosion, storm water controls). If a bullet trap is considered to be the only way to control the movement of lead munitions constituents on a range, then further investigation must be conducted to ensure that it will contain the lead. Even if it stops the bullet, there is still a possibility for lead to leach or wash out of the trap into the environment. A trap may provide some environmental benefit to a range, but its performance does not stop after the initial bullet impact. A review of the major categories of commercially available bullet traps, usage concerns, and implementation guidance is provided below.

Granular or Shredded Rubber Traps

Granular rubber traps consist of a layer or pile of shredded rubber produced from shredded tires. Bullets fired into the shredded rubber are retained within the bed of rubber. The thickness of the bed of rubber can be adjusted to accommodate the caliber of small arms ammunition being fired into it. Some of these traps require a steel framework to contain the rubber media; others have the option of being incorporated into existing berms. Those traps that require a steel framework will require a concrete foundation pad to be installed on the range to support the framework. Periodic removal of the bullet debris is conducted by a physical separation of the bullet debris from the rubber particles. Depending on the manufacturer, the bed of rubber may be exposed, covered with a rubber sheet, or amended with polymers or chemical additives to achieve various performance characteristics. A summary of the design variants, their associated performance traits, and performance concerns with respect to use on military small arms ranges is provided in Table 3-36. These performance concerns should be addressed prior to the purchase and installation of a granular or shredded rubber bullet trap on a small arms range.

Rubber Block Traps

Rubber block traps typically consist of sets of large blocks molded from shredded tires bound by an adhesive mixture. Bullets fired into the rubber blocks are retained within the rubber block. Block rotation or replacement is required when the fired rounds begin to penetrate the back of the blocks. These blocks may be installed with a rubber-coated steel back plate behind the blocks to capture rounds that penetrate the blocks.

Rubber block traps can effectively capture and contain small arms rounds, but there are several concerns with their use on military small arms ranges. The following performance concerns should be investigated prior to purchasing and installing a rubber block trap.

- Exposure to precipitation may result in transport of lead dust or colloidal lead from the trap.
- The trap may freeze into a solid mass in cold weather, creating a ricochet hazard.
- Heat might build up within the rubber blocks due to the friction of the rubber stopping the rounds. This heat buildup can result in the rubber catching on fire. Heat buildup is known to occur under automated firing scenarios. Other conditions under which heat buildup may occur are not well defined.
- Rubber may serve as a fuel to range fires.
- Spent rubber media after lead separation will be a hazardous waste when removed from the range based on Toxicity Characteristic Leaching Procedure (TCLP) characteristics for lead. Lead separation processes and efficiency are not well defined.

TABLE 3-36. GRANULAR/SHREDDED RUBBER BULLET TRAP VARIANTS

Trap Variant	Performance Characteristics	Performance Concerns
Exposed Rubber Bed	• Captures rounds • Tracer rounds cannot be used	• Physical condition of rounds depends on the type of munition and distance from firing point to the trap. High-velocity rounds may fragment within the rubber media. • Exposure to precipitation may result in transport of lead dust or colloidal lead from the trap. • Trap may freeze into a solid mass in cold weather, creating a ricochet hazard. • Heat might build up within the bed of granular rubber due to friction of granular rubber stopping the rounds. May result in the rubber catching on fire. May occur under automated firing scenarios. Conditions under which heat buildup occurs are not well defined. • Rubber may serve as a fuel to range fires. • Spent rubber media after lead separation will be a hazardous waste when removed from the range based on TCLP characteristics for lead. Lead separation processes and efficiency are not well defined.
Exposed rubber bed with chemical fire retardant amendments	• Captures rounds • Tracer rounds can be used	• Physical condition of rounds depends on type of munition and distance from firing point to the trap. High-velocity rounds may fragment within the rubber media. • Exposure to precipitation may result in transport of lead dust or colloidal lead and fire retardant chemicals from the trap. • Trap may freeze into a solid mass in cold weather, creating a ricochet hazard. • Heat might build up within the bed of granular rubber due to friction of granular rubber stopping the rounds. May occur under automated firing scenarios. May result in the rubber catching on fire, depending on fire retardant capabilities of the chemical amendment. Conditions under which heat buildup occurs are not well defined. • Replenishment frequency of fire retardant amendments may depend on site-specific environmental exposure characteristics. • Tracer round use may initiate a fire within the rubber media, depending on fire retardant capabilities of the chemical amendment.

See legend at end of table.

TABLE 3-36 (CONT'D)

Trap Variant	Performance Characteristics	Performance Concerns
		• Rubber may serve as a fuel to range fires, depending on fire retardant capabilities of chemical amendments. • Spent rubber media after lead separation will be a hazardous waste when removed from the range based on TCLP characteristics for lead. Lead separation processes and efficiency are not well defined.
Exposed rubber bed with super-absorbent polymers, chemical fire retardant, and lead stabilizing amendments	• Captures rounds • Tracer rounds can be used • Nonflammable media characteristics • Total lead containment (no leachable lead)	• Physical condition of rounds depends on type of munition and distance from firing point to the trap. High-velocity rounds may fragment within the rubber media. • Trap may freeze into a solid mass in cold weather, creating a ricochet hazard. • Spent rubber media after lead separation may be a hazardous waste when removed from the range based on TCLP characteristics for lead. Lead separation processes and efficiency are not well defined. • Trap hydration-level monitoring may require frequent measurement and adjustment.
Covered rubber bed	• Captures rounds • Tracer rounds cannot be used • Total lead containment (no leachable lead)	• Physical condition of rounds depends on type of munition and distance from firing point to the trap. High-velocity rounds may fragment within the rubber media. • Exposure to precipitation may result in transport of lead dust or colloidal lead, depending on the condition of the rubber cover and its ability to prevent infiltration into the trap. • Heat might build up within the bed of granular rubber due to friction of granular rubber stopping the rounds. May occur under automated firing scenarios. May result in the rubber catching on fire. Conditions under which heat buildup occurs are not well defined. Rubber cover may inhibit combustion by depriving the heated zone of adequate oxygen to support combustion; this may depend on condition or installation of rubber cover.

See legend at end of table.

TABLE 3-36 (CONT'D)

Trap Variant	Performance Characteristics	Performance Concerns
		• Rubber may serve as a fuel to range fires. • Spent rubber media after lead separation will be a hazardous waste when removed from the range based on TCLP characteristics for lead. Lead separation processes and efficiency are not well defined.
Covered rubber bed with leachate collection system	• Captures rounds • Tracer rounds can be used (claim specific to one manufacturer) • Total lead containment (no lead released)	• Physical condition of rounds depends on type of munition and distance from firing point to the trap. High-velocity rounds may fragment within the rubber media. • Precipitation that infiltrates the trap or condensation that forms within the trap will be collected by leachate collection system. This water may require either treatment prior to release to the environment or disposal as a hazardous waste. • Heat might build up within the bed of granular rubber due to friction of granular rubber stopping the rounds. May occur under automated firing scenarios. May result in the rubber catching on fire. Conditions under which heat buildup occurs are not well defined. Rubber cover may inhibit combustion by depriving the heated zone of adequate oxygen to support combustion. This may depend on condition or installation of the rubber cover. • Tracer round use may initiate a fire within the rubber media, depending on oxygen-inhibiting ability of rubber cover, which may depend on condition of the cover. • Rubber may serve as a fuel to range fires. • Spent rubber media after lead separation will be a hazardous waste when removed from the range based on TCLP characteristics for lead. Lead separation processes and efficiency are not well defined.

TCLP = Toxicity Characteristic Leaching Procedure.

Steel Trap with Deceleration Chamber

A steel trap with a deceleration chamber typically consists of steel plates on top, bottom, and sides. The top and bottom plates are set at an angle from horizontal to deflect bullets into an enclosed chamber. The bullets entering this chamber either spin around or strike a series of impact plates until the round loses energy and drops into a collection bucket. The bullet debris is periodically removed from the buckets for recycling. Variations between steel deceleration trap designs from various manufacturers are typically in the angle of the deflector plates, the means of stopping the rounds within the deceleration chamber, and the means of controlling lead particulate in the deceleration chamber.

Traps with low deflector plate angles with respect to horizontal should have less wear from round impacts than those with higher angles. In addition, the lower-velocity rounds (pistol rounds) are more likely to remain intact when they impact the low-angle deflector plates. The high-velocity rounds (rifle and machinegun rounds) will generally break up on impact with the deflector plates, but at the low angles these rounds may cause less wear on the plates than they would if the plates were installed at a higher angle to horizontal.

Another variation in the deceleration chamber designs from various manufacturers is the means in which the bullet is eventually stopped. Once the rounds enter the chamber, they typically either spin within the cylindrical chamber until they lose momentum and drop into a bucket or they impact a series of impact plates until the bullet debris loses momentum and drops into a bucket. The wear rates and characteristics on these two basic designs have not been thoroughly researched with respect to military use; thus, maintenance requirements and frequency are not known. These deceleration chambers are expected to experience wear and ultimate failure, which will have to be addressed by an inspection and maintenance program conducted throughout the life of the trap.

The final major variation in the deceleration chamber designs from various manufacterers is the control of lead dust generated in the chamber. Some trap designs have no means of controlling lead dust. This can result in a dust cloud forming in the chamber during use that will also exit the chamber, resulting in a release of airborne dust particles on and around the bullet trap. This release presents an exposure hazard to range maintenance personnel and, possibly, to the range user. One manufacturer uses a mineral oil that coats the rounds either on impact with the deflector plates or within the deceleration chamber. The mineral oil suppresses aerial dust formation. The oil is circulated through the trap by a filtered pumping system. Once this oil has reached the end of its useful life, the spent oil will require disposal as a hazardous waste when removed from the range. The third common variant of the deceleration chamber design is the use of a high-efficiency particulate air (HEPA) filtered ventilation system to extract aerial dust from the deceleration chamber during use to minimize the release of lead dust to the environment. This system reduces the emission of dust from the trap, but measurable emissions have still been detected.

Steel traps with deceleration chambers can effectively capture small arms rounds, but there are several concerns with their use on military small arms ranges. The following performance and installation concerns should be investigated prior to purchasing and installing this type of trap.

- Exposure to precipitation may result in transport of lead dust or colloidal lead from the trap. This is a concern for traps that cannot control the lead dust within the deceleration chamber. In addition, it is possible that all of the bullet dust and debris that forms upon impact with the deflector plates may not enter the deceleration chamber. This material may also present a source for lead transport away from the trap. Prior to purchase, it must be determined whether the bullet debris for the types of rounds being used on the range will be contained within the trap.

- The bullet debris that is collected by the trap is a recyclable material. Collection of the debris will require proper PPE, and personnel performing the collection and any other bullet trap maintenance should be trained and monitored for lead exposure. Spent material (filters, oil, damaged plate, etc.) will be a hazardous waste when removed from the range based on TCLP characteristics for lead. The cost of training, monitoring, PPE, and waste disposal should be expected to be higher than the value of the recyclable metals and will add to the range operation and maintenance expense. Personnel training, PPE, monitoring requirements, and trap maintenance requirements should be determined prior to purchase.

- Traps that use a HEPA-filtered ventilation system to control lead dust should conduct a dioctyl phthalate (DOP) smoke test in accordance with MIL-STD-282 (ref 59) when installed and after filters are changed to ensure the HEPA filters are effectively removing particulates from the air. This test rates HEPA filters by the percentage of 0.3-micron-sized particles of DOP smoke they remove. The use of a system that fails this test may result in a substantial release of lead dust to the environment.

- The trap design must support the intended use of the range. The shot dispersion and types of rounds being fired could result in ricochet problems or damage to the trap if range use is not considered in trap selection. Similarly, the use of a bullet trap may limit the use of a range if the range training mission changes. Changes in range use after the bullet trap installation may result in ricochet and trap damage issues.

- Steel traps require a concrete foundation pad to be installed on the range to support the trap. In addition, electrical service will be required on the range to operate the ventilation or pumping systems in some trap designs. These requirements will result in additional operation and maintenance cost to range use.

Shock-Absorbing Concrete (SACON)

SACON is a low-density, fiber-reinforced, foamed concrete developed by ERDC - Waterways Experiment Station (WES) for use in the construction of live-fire training facilities such as grenade houses and Military Operations in Urban Terrain (MOUT) villages. SACON was developed to minimize the hazard of ricochets during urban training. This property also creates a medium for capturing bullets. When properly designed, SACON provides a means of effectively capturing and containing lead in a variety of small arms range uses. It can be used as a backstop material or as a nonricocheting construction material on small arms ranges. Because of its alkaline nature, it can inhibit leaching of lead corrosion products, resulting in a lead stabilization capability. The waste generated by SACON use does not exhibit the hazardous waste characteristic for lead and can be disposed of as a solid waste when removed from the range. Use of the material can be limited by the following factors:

- Concentrated firing on the SACON can result in rapid wear and failure if not properly designed. SACON bullet traps that will receive concentrated fire as typically seen in a 25-meter range backstop application should be a minimum of 8-feet thick to allow a stable debris-filled bullet pocket to develop. Below this thickness, there is the potential for shoot-through of the trap under a concentrated firing scenario.

- Other than a backstop application and its use in MOUT and other live-fire training facilities, the primary use of SACON on ranges is typically as a nonricocheting construction material or as a protective barrier for equipment or utilities that may be near the normal line of fire. These applications will typically experience infrequent impacts from small arms rounds and may be designed for ease of construction and maintenance.

- Although the spent material (fragments of SACON and bullet debris) will be a solid waste, it still will contain lead. When performing maintenance, there is a potential for personnel exposure to lead dust. The cost of personnel training, monitoring, and PPE will add to the range operation and maintenance expense.

Maintenance Requirements: Maintenance requirements will vary with the type of trap selected, types of rounds used on the range, frequency of range use, weather exposure, etc. The maintenance requirements for each trap should be thoroughly researched prior to selection to ensure that adequate resources are budgeted and available to support the use of the trap. As a minimum, the traps should be inspected quarterly for excessive wear and damage. Repairs should be implemented immediately to ensure the safe and sustained use of the trap. Personnel should be trained to inspect and maintain the trap while using the appropriate PPE to minimize exposure to lead dust.

Cost Elements: The selection or development of a bullet trap to control the spread of lead munitions constituents requires a detailed description of the current and proposed future use of a specific range to ensure that a trap is either selected or developed that will function properly within those defined range operating parameters. Improperly matching range use with bullet trap function characteristics can result in high maintenance costs or premature failure of the trap. An experienced engineer should be involved in the selection or development of a bullet trap for a range to ensure that range and bullet trap operational and maintenance issues are minimized. The typical cost elements associated with this BMP are presented in Table 3-37. The major factors that can affect the performance and cost of this BMP are improper design and improper maintenance.

TABLE 3-37. BULLET TRAP COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	Annual Operation and Maintenance		
Bullet trap purchase or fabrication	Labor to inspect and maintain bullet trap	Document maintenance	Bullet trap overhead
Surveying	Utilities (if required)	Environmental management plan development and maintenance	Range downtime
Bullet trap design	Labor to manage hazardous waste	Reporting requirements	Bullet trap replacement
Planning	Hazardous waste disposal fees	Waste test/analyses	Demobilization or disposal at end of bullet trap useful life
Contracting	Management of recyclable material	Waste transportation (on- and off-range)	
NEPA documentation	Consumable materials	Safety training	
Construction permitting	Ongoing training of O&M personnel (if required)		
Site preparation (i.e., foundation preparation/ installation, utility installation) (varies with the type of trap selected)			
Labor to support bullet trap installation			
Miscellaneous material to support bullet trap installation			
Equipment rental (lifting and handling equipment, tools)			
Training of O&M personnel			

NEPA = National Environmental Policy Act.
O&M = Operation and maintenance.

3.4 Lead Removal

Periodic removal of lead from the range is a range management activity that may control the migration of lead by removing the source. This method of managing lead on ranges is very expensive and will result in significant range downtime during the maintenance event unless only a targeted removal of the concentrated lead deposition areas immediately behind the targets is performed. Lead removal should be considered a last resort in lead management methods. It should be proposed only when other lead migration and pollution prevention methods have been exhausted.

Metals (Lead) Removal

Description: Lead may be removed from a range by physical separation methods alone or by a combination of physical and chemical (soil washing) separation methods. The most efficient method of lead removal will be site-specific. The factors involved are soil physical and chemical characteristics, moisture content, lead physical and chemical characteristics, and organic content. There are five classes of physical separation techniques: (1) size separation (screening), (2) hydrodynamic separation (classification), (3) density (gravity) separation, (4) froth flotation, and (5) magnetic separation. The fifth separation technique, magnetic separation, is typically not applicable to the type of metals found in small arms rounds. After physical separation, which will remove the coarse particulate metals, an acid leaching (soil washing) process may be needed to remove the lead remaining in the soil either as fine particulates or as molecular or ionic species bound to the soil matrix (ref 60). Lead removal may focus on the entire area of small arms round impacts of a given range, or the removal may be focused on only the points of highest concentrations or round impacts (i.e., bullet pockets on berms). The focus of the lead removal will depend on the lead mobility from the area and the lead migration characteristics or exposure potential present in the range area.

Benefit: Periodic metal source removal provides a means of controlling the accumulation and dispersion of lead, thus minimizing the impact of small arms range use on the environment.

Applicability: Lead removal is applicable anywhere that small arms round metal constituents have accumulated and other lead migration or pollution prevention methods cannot effectively control migration of the metals.

Limitations: Lead removal from range areas is very expensive and will result in significant range downtime during the maintenance event. Recycling facilities may refuse to accept materials that do not meet minimum lead requirements, which vary from 20 percent to 99 percent lead depending on facility capabilities (ref 61). When lead percentages are low in the recovered product, it may be necessary to dispose of material as hazardous waste or pay to have it accepted at recycling facilities (ref 61).

Implementation Guidance: To determine the best method to remove the lead, two basic steps must be taken.

1. The lead removal goal for the maintenance action must be determined. For example, if lead is being removed to mitigate a ricocheting issue with the accumulated metal, then the lead removal action need only remove the metal particle size fraction that creates the ricochet hazard. This would probably result in a simple screening process as the removal method. However, if lead removal is desired to mitigate the transport of lead in storm water runoff or the leaching of lead to the groundwater, then a very aggressive lead removal goal must be established to ensure that the lead fine particulates, as well as the molecular and ionic species bound to the soil matrix, are removed. This will require the much more expensive combination of physical and acid leaching processes. Simply removing the coarse particulate lead will not mitigate a lead transport problem because the coarse lead is not the lead that is being transported. The smallest fraction is being transported, and this is the most expensive fraction to remove.

2. Since the most efficient removal method will be site-specific, a bench scale treatability study will be required to determine the most efficient method to reach the established lead removal goal. Treatability studies can be conducted in accordance with the Final Implementation Guidance Handbook - Physical Separation and Acid Leaching to Process Small Arms Range Soils (ref 60).

The four classes of physical separation techniques, along with a summary of their attributes that may be applicable to separating lead and other small arms related metals from soil, are presented in Table 3-38.

After physical separation, the coarse particulate metals have been removed from the soil. The remaining lead and other metals in the soil are fine particulates or ionic species bound to the soil matrix. The fine particulates may be either elemental lead particles or lead salts. To remove this remaining fraction of lead from the soil, a soil washing (or acid leaching) process is needed. Acid leaching mobilizes the remaining lead fraction by lowering the pH of the wash solution. At the lower pH, the lead dissolves and can be separated or washed out of the soil matrix. The wash solution is then treated to extract the dissolved lead. The soil pH is neutralized using lime or other appropriate amendment to raise the pH to a neutral range (approximately 7), and then the soil is returned to the range (ref 60).

Maintenance Requirements: No range maintenance is required with respect to the removal operations. After removal operations are complete, sediment and erosion control measures should be implemented to stabilize the disturbed soil.

Cost Elements: The development of a successful lead removal strategy to control the spread of lead munitions constituents requires the knowledge of an experienced engineer. The typical cost elements associated with this BMP are presented in Table 3-39. The major factors that can affect the performance and cost of this BMP are improper design and improper maintenance.

TABLE 3-38. COMMON SEPARATION METHOD ATTRIBUTES[a]
(Source: USAEC, 1997)

Separation Method Attribute	Size Separation (Screening)	Hydrodynamic Separation (Classification)	Density (Gravity) Separation	Froth Flotation
Basic principle	Various diameter openings allow passage of particles of different size	Different settling rates due to particle density, size, or shape	Separation due to density differences	Particles are attracted to bubbles because of their surface properties
Major advantage	High-throughput continuous processing with simple, inexpensive equipment	High-throughput continuous processing with simple, inexpensive equipment	High-throughput continuous processing with simple, inexpensive equipment	Very effective for fine particles
Limitations	Screens can plug; fine screens are fragile; dry screening produces dust	Difficult when high proportions of clay, silt, and humic materials are present	Difficult when high proportions of clay, silt, and humic materials are present	Particulate must be present at low concentration
Typical implementation	Screens, sieves, or trammels (wet or dry)	Clarifier, elutriator, hydrocyclone	Shaking table, spiral concentration, jig	Air flotation columns or cells
Applicable particle-size range	Dry screen >3000 µm Wet screen >150 µm	50 to 150 µm	5 to 3000 µm	5 to 500 µm

[a]Modified from Reference 57.

TABLE 3-39. LEAD REMOVAL COST ELEMENTS

Direct BMP Costs		Indirect BMP/Environmental Costs	Other Costs
Startup	Annual Operation and Maintenance		
Lead removal treatability study	Labor to sample range soil	Document maintenance	BMP overhead
Planning	Soil analyses	Environmental management plan development and maintenance	Range downtime
Contracting	Consumable materials	Reporting requirements	
Permitting (if required)	Periodic soil removal from high lead concentration areas	Waste test/analyses	
NEPA documentation	Labor to support lead removal operations	Waste transportation (on- and off-range)	
Labor to support lead removal operations	Consumable materials to support lead removal operations	Safety training (if required)	
Consumable materials to support lead removal operations	Equipment rental		
Equipment rental	Labor to manage hazardous waste		
Labor to manage hazardous waste	Hazardous waste disposal fees		
Hazardous waste disposal fees			
Management of recyclable material			

NEPA = National Environmental Policy Act.

4. Evaluation of Small Arms Range Sustainment Method Performance

This section attempts to identify relatively simple methods of evaluating the performance of BMPs installed in small arms range training areas to control metals transport from these areas. Evaluating the performance of many of the BMPs identified in this manual can be very difficult because performance can often vary with many site-specific or event-driven parameters. In addition, BMP performance itself can be defined in many different ways. These are primarily issues associated with storm water transport and evaluation of their BMPs, but they may also factor into some of the other transport pathways and BMPs designed to address them. The following subsections will discuss each transport pathway, the major performance goals associated with BMPs designed to address these pathways, and potential methods of evaluating BMP performance with respect to the transport pathway.

4.1 Storm Water Transport

As previously discussed in paragraph 2.3.1 of this manual, storm water runoff from range areas represents the most likely mechanism for metals residues and eroded soils/sediments to be transported off-range. Runoff waters can carry solid particles of metal or metal adsorbed to soil particles as part of the suspended sediment load. Runoff waters can also carry dissolved metals within the water, although dissolved metals are usually a very small percentage of the total metals transported in storm water runoff.

The primary goal of BMP(s) implemented to address storm water transport is the reduction of TSS and total metal concentrations in the runoff to water quality levels that are protective of human health. Another goal is to minimize the damage that runoff causes to training areas to sustain training operations and minimize range downtime for maintenance.

Storm water runoff sediment and munitions metals loads are highly variable. This variability can affect the performance of a storm water BMP or system of BMPs and can be caused by a number of factors. Depending on the BMP(s) implemented, its performance may vary by rainfall intensity, runoff volume, runoff flow rate, seasonal variations in site conditions (precipitation, vegetative cover, freeze/thaw cycles, etc.), variations in training area use (seasonal throughput, changes in training scenarios, or weapons use), and conformance to maintenance schedules. This makes the comparison of pre- and post-BMP implementation data to determine overall removal efficiency for the BMP(s) difficult and generally not recommended. The limited data collected to establish baseline conditions prior to implementing the BMP(s) most likely will not reflect the same influences these factors have on the BMP performance at the time of sample collection for post-implementation sampling. In addition, for range management purposes, attempting to determine the efficiency of the BMP(s) by sampling inlet and outlet flows of the BMP systems is not recommended. These data and efficiency analyses may be useful for regulatory reporting or statistically significant comparison of different BMP methods under similar flow conditions, but they are not needed for the simple determination of whether BMP goals have been met. If BMP efficiency analyses are desired, USEPA research into analysis techniques for development of performance measures for storm water BMP removal efficiency may be consulted (ref 62).

Prior to conducting an evaluation of BMP methods for storm water runoff, at least one full growing season (1 year) should be allowed for vegetation growth before evaluating performance. Two full seasons (years) of growth and establishment are more desirable to accurately judge the success of vegetation based BMPs.

The Step II storm water sampling guidance provided in paragraph 2.3.1 recommended multiple sampling events to attempt to determine the effects of rainfall intensity and seasonal variations on the runoff quality. This same sampling regimen is also recommended for post-BMP implementation sample collection. If Step II sampling was conducted, then samples from the same collection points should be collected for at least a 1-year period. If Step II sampling was not performed, then the storm water sampling guidance provided in paragraph 2.3.1 should be followed to develop a storm water sampling plan. As a minimum, natural stream channels should be sampled at locations near range storm water runoff entry points and downstream of the range areas to gauge the natural attenuation effects that sediment settling, dilution, and dispersion are having on water quality prior to reaching potential receptors. These results should be compared with the applicable water quality criteria identified during the evaluation. Successful achievement of these criteria can be equated to successful BMP performance.

The evaluation of the BMP(s) effects on erosion damage and maintenance requirements for the range can be based on visual observations of the range condition and maintenance records. Range checks should be conducted periodically and erosion conditions documented for comparison with the evaluation documentation of erosion conditions. Ideally, after BMP(s) have been implemented, the only wear on the range should be that associated with the direct impact of the rounds. Storm water runoff should not transport sediments away from the immediate area of the small arms round impacts. If sediment transport still occurs, then additional maintenance or management actions may need to be taken.

4.2 Groundwater Transport

Shallow groundwater metals contamination may occur as a result of dissolved or possibly colloidal metals transport from the munitions metals deposited in the surface soil. The formation of metal particles and metal ions is believed to be the result of round fragmentation upon impact and corrosion processes. Their transport to the shallow groundwater occurs through the soil pore fluid and rain infiltration. BMPs designed to address transport to the groundwater involve the installation of an impermeable barrier (clay or geotextile) under the shallow soils of the primary small arms round impact areas or the creation of a reactive zone under or within these areas that will precipitate and stabilize the mobilized metals. Any actions that attempt to control munitions metals that have already reached the groundwater would likely be considered cleanup actions that are beyond the scope of range management activities and the scope of this document.

The primary goal of BMP methods implemented to address groundwater transport is the reduction of munitions metal concentrations in the groundwater to water quality levels that are protective of human health and the environment. This is performed by sequestering lead at its source in the shallow soil layer.

Other than shallow groundwater remediation, no range BMP methods will have an impact on metals concentrations in groundwater over a short period of time. To evaluate performance of BMP methods implemented to sequester munitions metals in the shallow soils, a long-term groundwater monitoring program will need to be implemented. This monitoring should be performed at least once a quarter on a seasonal (summer, fall, winter, spring) schedule. The guidance for groundwater well installation and sample analysis provided in paragraph 2.3.1 of this manual should be followed, with the exception that permanent wells should be established to support an extended monitoring program.

No soil pore fluid or soil samples will provide a definitive measure of BMP performance. However, soil samples collected within the reactive zone and pore fluid samples collected below the reactive zones or impermeable barriers may provide an indication of overall BMP performance. This type of sampling and specialized analyses will require the support of environmental scientists experienced in the transport characteristics of munitions metal constituents. This activity should be coordinated with the USACE - ERDC-EL.

4.3 Surface Water Transport

When not under the influence of storm water runoff, surface water quality (streams, ponds, etc.) is governed by the quality of the shallow groundwater discharge that provides the base flow to the surface water resource and the direct or indirect deposit of lead into the water body. Any BMP that controls storm water sediment movement, sequesters transport to groundwater, or limits the direct or indirect deposit of metals into a water body will ultimately mitigate the potential for base flow surface water transport of munitions metal constituents from the range area. One of the primary goals of BMP(s) implemented in small arms range areas is the reduction of metals concentrations in the base flow surface water to water quality levels that are protective of human health.

As stated in paragraph 2.3.1, sampling a surface water resource's base flow may provide some insight into the overall watershed health as it relates to small arms range use. Sampling of the base flow is recommended prior to the initiation of a small arms range BMP. The base flow sampling will provide a baseline of current water quality that reflects past and ongoing metals migration within the watershed. Long-term base flow monitoring results collected after BMPs are implemented can then be compared with this baseline to gauge the ongoing effects, if any, that continued range use and BMPs have on general surface water quality. These results can also be compared with the applicable water quality criteria identified during the evaluation. Successful achievement of these criteria can be equated to overall successful BMP program performance within the watershed. Sampling and analyses should be conducted using the guidance provided in paragraph 2.3.1.

4.4 Aerial Transport

Aerial transport of munitions metal constituents at firing ranges may occur when bullets are fired into dry soil on the impact berms and as a result of wind transport. The dusts of fine soil particles likely contain some quantity of metals from fragmenting or corroding bullets. These dusts typically do not travel far from the immediate range area before being deposited back on the soil surface.

The goals of BMP(s) implemented to address aerial transport of munitions metal constituents are reducing airborne metals levels to levels protective of human health and limiting the spread of metals to the immediate impact area of the rounds.

Sampling and analysis to determine the extent of aerial transport after BMP(s) are implemented may be conducted using the guidance provided in paragraph 2.3.1. Air sampling to determine the concentrations of potential metals-contaminated dusts in areas that may potentially reach human receptors may be conducted using high-volume air samplers. The air sampling results can also be compared with applicable air quality criteria identified during the evaluation. Successful achievement of these criteria can be equated to overall successful BMP performance to control aerial transport.

5. Cost Estimation and Economic Assessment

The BMPs selected to address potential environmental issues on small arms ranges must address the metals migration or erosion issue in a cost-effective manner. In many cases, several BMPs will be suitable for addressing the identified environmental issue. To identify the most cost-effective BMP, a consistent method of identifying and quantifying capital and maintenance costs must be used to compare BMP methods and to appropriately budget for BMP installation and maintenance. To support the economic analyses of BMPs, the Environmental Cost Analysis Methodology (ECAM) Handbook is recommended (ref 19). The ECAM Handbook and software are available for downloading from the ESTCP Web site http://www.estcp.org/pi_resources/index.cfm. The Handbook provides practical guidance for applying ECAM and improving the identification and assignment of conventional and environmental costs.

The ECAM tool should facilitate the gathering and analysis of economic data to evaluate the investments in small arms range BMPs. Conducting an ECAM to at least a level II analysis is recommended. Estimates should be made based on similar costs incurred or through the use of standardized data such as the most current RS Means Building Construction Cost Data or RS Means Site Work and Landscape Cost Data, which is generally available at local public libraries.

An example ECAM cost reporting table template that has been modified to support small arms range BMP cost analyses is presented in Table 5-1. The table shows the typical cost categories that may apply to BMP implementation and maintenance. Not all of the costs in Table 5-1 apply to all BMPs, but they should be considered as a minimum when evaluating BMPs or budgeting for BMP implementation and maintenance.

The startup or capital costs are those that are involved in the design, purchase, fabrication, installation, and preparations for operation of the BMP (e.g., permitting, NEPA documentation, surveying, engineering support, planning and coordination with appropriate installation departments, materials, contracting, labor, equipment rentals).

O&M costs primarily consist of those associated with maintaining the installed BMP; however, some BMPs (i.e., some bullet traps) do require operators for the BMP to perform effectively. Costs that are often missed are hazardous waste disposal costs, consumable material costs, and training of operators and maintenance personnel for some BMPs.

Indirect environmental costs must be considered when estimating BMP implementation and maintenance costs. Depending on the BMP selected, significant environmental documentation may be required to be maintained throughout the life of the BMP. These activities should be reviewed with the installation environmental office to ensure that all costs are captured during the initial cost analyses of the potential BMPs.

Other costs are those that do not fit into the previous categories. They may be recurring costs or a one-time cost such as demobilization and disposal. For example, if a bullet trap has reached the end of its useful life, whether because of wear or changes to range use, the disposal cost of the trap must be factored into the overall life cycle cost of using the trap. These removal and disposal costs may be significant, especially if the bullet trap material must be handled and disposed of as a hazardous waste.

An appropriate life cycle period must be selected in order to compare competing BMP costs. Selection of an appropriate life cycle period can vary from range to range and be based on a number of factors (e.g., the life cycle of the weapons system used on the range, training-based plans for future range upgrades or modifications, installation mission changes, etc.). Selecting an appropriate life cycle period for a range facility can be difficult, but a realistic estimate is necessary to make accurate comparisons between BMPs.

TABLE 5-1. TYPICAL BMP COSTS BY CATEGORY

Direct BMP Costs				Indirect BMP/Environmental Costs		Other Costs	
Startup		Annual O&M					
Activity	**Cost, $**	**Activity**	**Cost, $**	**Activity**	**Cost, $**	**Activity**	**Cost, $**
BMP equipment purchase		Labor to operate and maintain BMP		Environmental permitting (if required)		BMP overhead	
Surveying		Labor to manage hazardous waste		Document maintenance		Range downtime	
BMP design		Utilities		Environmental management plan development and maintenance		BMP equipment replacement	
Planning		Hazardous waste disposal fees		Reporting requirements		Demobilization or disposal at end of BMP useful life	
Contracting		Management of recyclable material		Waste test/analyses			
Construction permitting		Consumable materials		Waste transportation (on- and off-range)			
Labor for BMP installation		Ongoing training of O&M personnel (if required)		Safety training (if required)			
Material for BMP installation							
Equipment rental							
Training of O&M personnel (if required)							
NEPA documentation							

NEPA = National Environmental Policy Act.
O&M = Operation and maintenance.

6. Range Sustainment Funding Sources

The Sustainable Range Program is the Army's overall approach for improving the way it designs, manages, and uses its ranges and training lands to meet its training responsibilities. The goal of this program is to maximize the capability, availability, and accessibility of ranges and training lands to support training and test requirements (ref 63). Army Regulation (AR) 350-19, The Army Sustainable Range Program was issued in August 2005. This AR integrates the Range Training Land Program (RTLP) and Integrated Training Area Management (ITAM) programs to improve overall design and management of ranges. This guidance manual is intended to support the training range availability and accessibility aspects of range management.

Funding of the Sustainable Range Program is carried out in accordance with the Army's Planning, Programming, Budgeting, and Execution System (PPBES). Range maintenance or modification funding requirements need to be submitted to the Program Objective Memorandum (POM) within established management timelines. Various funding sources are available to support the sustainment of Army small arms ranges (ref 64). The type of funds that can be used to support the modification or maintenance of a small arms range depends on the operation or the reason the work is being performed. The funding sources have specific requirements or limitations on how they are appropriately used. Examples of various situations that may require different funding sources would be if the action on the range is a one-time effort to bring the range into environmental compliance or if the action performed is range modernization or routine range maintenance. Each funding source has requirements that must be met in order to be eligible for receipt and use of those funds. The various Army funding sources that may be applicable to range projects are presented in Table 6-1.

TABLE 6-1. RANGE MODIFICATION FUNDING SOURCES

Funding Type	Funding Program	MDEP Code
Range sustainment	ITAM	TATM
	Range operations	VSCW
	Real property maintenance program	QRPA
	Real property services	QDPW
	Environmental support to ranges and munitions	VEMR
	Range modernization	VSRM
Range compliance	Environmental compliance	VENC
	Environmental pollution prevention	VEPP
Range conservation	Environmental conservation	VENN

ITAM = Integrated training areas management program.
MDEP = Management Decision Packages.

6.1 The ECS Methodology

The Environmental Program Requirements (EPR) are the primary means for Army managers to identify and document all current and projected environmental requirements and resources needed to effectively execute environmental programs. Beginning with POM FY2008 through FY2013, the EPR Cost Standardization (ECS) Methodology will be used to develop cost requirements for the Management Decision Packages (MDEPs): VENC, VENN, VEPP, and VEMR. Headquarters, Department of the Army (HQDA) will no longer require the EPR data submission previously provided by the EPR Report process to develop and validate these Environmental Quality Requirements (ref 65).

6.2 Range Modification Funding Sources

Range modification projects may be funded by a number of different sources, depending on the nature of the specific project. The paragraphs below describe the key programs and funding sources that support range sustainment. A summary of MDEPs, proponents, related appropriations, and authorized executers is presented in Table 6-2.

It is critical that the installation Range Officer and the related supporting garrison staff elements (including the Directorate of Public Works and the environmental office) work together to determine the appropriate program and funding source for a given project based on the policy and guidance for each of the supporting range sustainment programs (ref 66).

TABLE 6-2. PROGRAM EXECUTION GROUP (PEG) MDEP RELEVANT TO SRP

MDEP Code	Function	HQDA Proponent	APPN	Executed By	Remarks
TATM	ITAM core capabilities	G3-DAMO-TRS	OMA, OMAR, OMNG	• IMA, IMA regions, and garrison DPTMs in CONUS • TRADOC-ATSC • Army Environmental Center • Service school base • USAREUR 7ATC • USARPAC, Deputy Chief of Staff, G-3 • 8th U.S. Army, Deputy Chief of Staff, G-3 • ATEC, DCSELE • State ARNGs	RTLA, TRI/ ATTACC, SRA, LRAM, and GIS
VSCW	Range operations	G3-DAMO-TRS	OMA, OMAR, OMNG	• IMA, IMA regions, and garrison DPTMs CONUS • USACE HNC • TRADOC - ATSC • USAREUR 7ATC • USARPAC, Deputy Chief of Staff, G-3 • 8th U.S. Army, Deputy Chief of Staff, G-3 • ATEC, DCSELE • State ARNGs	Range division civilian pay in AC and USAR; some reimbursable State employees in the ARNG; expendables; local contracts, NEPA for range projects

TABLE 6-2. (CONT'D)

MDEP CODE	Function	HQDA Proponent	APPN	Executed By	Remarks
QRPA	SRM	ACSIM-DAIM-MD	OMA, OMAR, OMNG	OMA and OMAR by the IMA; IMA regions and garrison DPWs; OMNG by State ARNGs	Fixed firing ranges and range training facilities; MOUT
QDPW	Real property services	ACSIM-DAIM-MD	OMA, OMAR, OMNG	OMA and OMAR by the IMA; IMA regions and garrison DPWs; OMNG by State ARNGs	Range area: erosion, water quality issues, natural resource issues, grounds maintenance and waste disposal
VEMR	Operational ranges	ACSIM-DAIM-ED	OMA, OMAR, OMNG	IMA, IMA regions, garrison DPW, lead organizations, USAEC	
VSRM	Range modernization	G3-DAMO-TRS	OMA, OMAR, OMNG, MCA, MCAR, MCNG, RDTE, OPA3, MSLS	• Lead organizations • USACE HNC • PEO STRI	Range modernization O&M projects, range modernization MILCON projects, range targetry and technology
VENC	Environmental compliance	ACSIM-DAIM-ED	OMA, OMAR, OMNG	IMA, IMA regions, garrison DPW, lead organizations, USAEC	Federal, State, and local laws, regulations, and agreements
VEPP	Pollution prevention	ACSIM-DAIM-ED	OMA, OMAR, OMNG	IMA, IMA regions, garrison DPW, lead organizations, USAEC	
VENN	Conservation	ACSIM-DAIM-ED	OMA, OMAR, OMG	IMA, IMA regions, garrison DPW, lead organizations, USAEC	Installation and tenant activities

AC = Active Component.
ACSIM = Assistant Chief of Staff for Installation Management.
APPN = Appropriation.
ARNG = Army National Guard.
ATC = U.S. Army Aberdeen Test Center.
ATEC = U.S. Army Test and Evaluation Command.
ATSC = Army Training Support Center.
CONUS = Continental United States.
DAIM = Department of the Army's Assistant Chief of Staff for Installation Management.
DAMO-TRS = Department of the Army Management Office - Training Simulations.
See legend on next page.

TABLE 6-2 (CONT'D)

DCSELE	=	Deputy Chief of Staff for Engineering, Logistics, and Environment.
DPTW	=	Directorate of Plans, Training, and Mobilization.
DPW	=	Department of Public Works.
GIS	=	Geographic Information Systems.
IMA	=	Installation Management Agency.
ITAM	=	Integrated Training Area Management.
LRAM	=	Land Rehabilitation and Maintenance.
MACAR	=	Military Construction, Army Reserve.
MACOM	=	Major Army Command.
MCA	=	Military Construction, Army.
MCNG	=	Military Construction, National Guard.
MDEP	=	Management Decision Packages.
MILCON	=	Military construction.
MOUT	=	Military Operations in Urban Terrain.
MSLS	=	Missile Procurement.
NEPA	=	National Environmental Policy Act.
O&M	=	Operation and maintenance.
OMA	=	Operations and maintenance, Army.
OMAR	=	Operations and maintenance, Army Reserve.
OMNG	=	Operations and maintenance, Army National Guard.
OPA3	=	Other Procurement, Army.
QRPA	=	Real Property Maintenance.
PEG	=	Program Execution Group.
PEO STRI	=	Program Executive Office Simulation, Training, and Instrumentation.
RDTE	=	Research, development, test, and evaluation.
SRA	=	Sustainable Range Awareness.
SRM	=	Sustainment, Revitalization and Maintenance.
TRADOC	=	Training and Doctrine Command.
TRI	=	Training Requirements Integration.
USACE HNC	=	United States Army Corps of Engineers Huntsville Engineering Support Center.
USAEC	=	U.S. Army Environmental Center.
USAR	=	United States Army Reserve.
USAREUR	=	United States Army, European Command.
USARPAC	=	United States Army, Pacific Command.

6.2.1 Range Sustainment

Two funding sources are available. The MDEP TATM funds support range work through the installation's ITAM group. The TATM funds are available specifically for actions related to keeping the ranges and training areas operable. The MDEP VSCW funds support training range operations and maintenance activities.

ITAM Program (MDEP TATM)

The ITAM program is the Army's formal strategy for focusing on sustained use of training and testing lands. The intent of the ITAM program is to systematically provide a uniform training land management capability across the total Army. The four components of ITAM work in unison to accomplish the ITAM mission: Training Requirements Integration (TRI), Range and Training Land Assessments (RTLA), Land Rehabilitation and Maintenance (LRAM) and Sustainable Range Awareness (SRA).

RTLA is a management procedure that inventories and monitors land conditions. It incorporates relational database and GIS technologies into the land use decision process. RTLA collects physical and biological resources data from training land in order to relate land conditions to training and testing activities. These data provide the information to effectively manage land use and natural and cultural resources.

TRI is a decision support procedure that integrates all requirements for land use with natural and cultural resources management processes. TRI integrates the installation training and testing requirements for land use derived from the Range and Training Land Program, the range operations and training land management processes, and the installation's training readiness requirements with the installation's natural resources conditions. The Army Training and Testing Area Carrying Capacity (ATTACC) program is the standard ITAM methodology for estimating training land-carrying capacity by relating training load, land condition, and land maintenance practices. The integration of all requirements occurs through continuous consultation among the Directorate of Plans, Training, and Mobilization (DPTM), natural and cultural resources managers, and other environmental staff members. The output of the TRI process is incorporated in the installation's Integrated Natural Resources Management Plan.

LRAM is a preventive and corrective land rehabilitation and maintenance procedure that reduces the long-term impacts of training and testing on an installation. It mitigates training and testing effects by combining preventive and corrective land rehabilitation, repair, and maintenance practices. It includes training area redesign and reconfiguration to meet training requirements.

SRA provides a means to educate land users on their environmental stewardship responsibilities. It provides for the development and distribution of educational materials to land users. These materials relate the principles of land stewardship and the practices of reducing training and testing impacts. SRA also includes information provided to environmental professionals concerning operational requirements.

ITAM funding supports the ITAM mission, goals, objectives, and core capabilities and is not used to

- correct statutory compliance requirements.
- perform routine range maintenance or modification or Sustainment, Revitalization and Maintenance (SRM) responsibilities.
- perform Army conservation program requirements, such as the planning-level survey (PLS).
- fund reimbursable environmental research and development at the lead organization or installation level.

The installation proponent for TATM funds is the ITAM coordinator with the Range Officer. Installations identify their ITAM resource requirements through their annual work plan submission Work Plan Analysis Module. As with other range sustainment projects, ITAM project requirements should be closely coordinated with the Range Officer, DPW, and environmental office staff elements.

Range Operations (MDEP VSCW)

Range Operations, MDEP VSCW, supports operation and maintenance of Army training ranges and airfields. The program provides installation range division manpower, contract support, and consumable supplies and materials. It includes expenses for maintenance of range technology and NEPA documentation for new ranges, as well as planning requirements at installation, lead organization, and HQDA levels. VSCW supports O&M costs for UXO clearance requirements related to construction or modernization activities on active ranges. It supports all Army training ranges, including MOUT training facilities, but does not support Combat Training Center (CTC) rotational live-fire facilities. VSCW provides centralized support of the Army-wide program to include projects managed by DAMO-TRS (proponent), Training and Doctrine Command (TRADOC) Army Training Support Center (ATSC) (executive agent), USACE Huntsville Engineering Support Center (HNC) (Facilities Program Management), STRICOM (technology development, acquisition, and support), and Program Executive Office, Standard Army Management Information Systems (PEO STAMIS) (management support system development and support).

VSCW funding is intended to support range operations and is not used to

- correct statutory environmental compliance requirements on ranges.
- perform routine range maintenance or modification or SRM responsibilities.
- perform Army conservation program or ITAM program requirements.
- accomplish UXO removal or clearance operations not directly associated with active range maintenance, construction, or modernization.

The installation proponent for VSCW funding is the Range Officer. Installations identify their VSCW resource requirements through their annual work plan submission of the Training Budget Utilization Document. Major and minor construction projects must follow the USACE 1391 process. The Army Master Range Plan (AMRP) is used to track and manage major range projects.

Sustainment, Revitalization and Maintenance (SRM) Program (MDEP QRPA)

The SRM program, MDEP QRPA, provides the principal funds to sustain all Army real property. Sustainment addresses maintenance and repair of real property, including fixed firing ranges and related facility structures such as towers and bunkers. QRPA can also fund minor construction not to exceed $300K (except safety and health not to exceed $1M) to add, expand, extend, alter, convert, replace, or relocate existing real property facilities. MDEP QRPA funds may be used to stabilize soils on maintained roads and trails and to maintain fixed firing ranges included in the installation facility system (IFS).

Typically, QRPA requirements are much greater than the funding provided. Installation range managers must ensure that range facilities are accurately accounted for in the IFS and that they work with DPW to receive the highest possible priority for QRPA funding to support range facilities maintenance.

QRPA funding is intended for real property maintenance and cannot be used to

- support range operations related costs covered by VSCW.
- correct statutory environmental compliance requirements on ranges.
- correct maneuver damage on training land covered by ITAM LRAM funding.
- accomplish UXO removal or clearance operations.
- accomplish range construction or modernization projects covered under VSCW or VSRM.

The installation proponent for QRPM funding is the DPW. Installations receive QRPA funding based on their IFS inventory, which is routinely submitted to HQDA Assistant Chief of Staff for Installation Management (ACSIM). It is critical that Range Officers work with DPW and compete for installation QRPA dollars to maintain range infrastructure.

Real Property Services (MDEP QDPW)

Real property services, MDEP QDPW, provides support services for all Army real property. This includes services to

- dispose of hazardous waste resulting from abatement and maintenance of buildings and general solid waste handling and disposal.
- provide grounds maintenance.

- manage sedimentation, natural erosion (excluding damage caused by training), dust control, and surface water resources in range and maneuver areas.

- provide latrine services for ongoing operations.

- protect and manage water resources in range and training areas (i.e., planting vegetation, using structural and nonvegetative measures of control dust, erosion and surface water, and management (not construction) of wetlands used for treatment of storm water).

- develop and implement open space and building pest management strategies. Includes control of invasive species, noxious weeds, and vegetative fire hazards in range and training areas (e.g., mowing, herbicide application, prescribed burning, maintenance of fire breaks).

Installation range managers must ensure that range facilities are accurately accounted for in the IFS and that they work with DPW to receive the highest possible priority for QDPW funding to support range services.

QDPW funding is intended for real property services and cannot be used to

- support range operations related costs covered by VSCW.

- correct statutory environmental compliance requirements on ranges.

- correct maneuver damage on training land covered by ITAM LRAM funding.

- accomplish UXO removal or clearance operations.

- accomplish range construction or modernization projects covered under VSCW or VSRM.

The installation proponent for QDPW funding is the DPW. Installations receive QDPW funding based on their IFS inventory, which is routinely submitted to HQDA ACSIM. It is critical that Range Officers work with DPW and compete for installation QDPW funding.

Environmental Support to Ranges and Munitions Program (MDEP VEMR)

The Environmental Range and Munitions support program, along with the MDEP VEMR, provides funds for environmental management on operational ranges in support of sustainable range management, actions necessary to conduct site-specific studies and assessments to characterize impacts of training and testing (including MEC and MC), to support compliance with environmental laws and to respond to imminent and substantial threats to human health and the environment. This includes programmatic studies (such as data gathering, monitoring, sampling, and data analysis to support the development of technical guidance), tools and methods for range sustainability, and munitions response. Program management costs include projects and personnel to provide applicable program management.

VEMR funding is intended to provide environmental support for ranges and cannot be used to

- perform routine range maintenance or modification or SRM responsibilities.
- correct maneuver damage on training land covered by ITAM LRAM funding.
- support range operations related costs covered by VSCW.
- accomplish UXO removal or clearance operations associated with active range construction or modernization.
- perform Army conservation program requirements, such as the PLS.

The installation proponent for VEMR funding is the Environmental Office Chief. Project-level descriptions are submitted using the ECS Methodology through the installation environmental office and flow through the garrison chain of command to HQDA for funding. Range Officers must work with the garrison environmental office for VEMR project funding.

Range Modernization Program (MDEP VSRM)

The Range Modernization Program, MDEP VSRM, supports construction related to modernizing Army ranges, including military construction, Army (MCA) projects over $500K, and minor construction (those under $500K). The Range Modernization Program has taken these requirements out of the VSCW MDEP to better track range construction projects. The program will also support acquisition and installation of range targetry and instrumentation under the suitable appropriation.

VSRM funding is intended to support range modernization and cannot be used to

- support range operations related costs covered by VSCW.
- perform routine range maintenance or modification or SRM responsibilities.
- accomplish UXO removal or clearance operations.

The installation proponent for VSRM funding is the Range Officer. Installations will identify their VSRM resource requirements through submission of AMRP project requirements and the 1391 process.

6.2.2 Range Compliance

The VENC and VEPP funds are available and applicable to modifying a small arms range for range compliance projects. Range compliance focuses on attaining and sustaining compliance with Federal, State, and local environmental laws and regulations when applicable to operational ranges. Projects designated as priority/must funds should be clearly identified as such so that requirements can be allocated from other sources to achieve compliance.

Environmental Compliance Program (MDEP VENC)

The Environmental Compliance Program, MDEP VENC, funds costs associated with installation and tenant activity compliance with environmental laws, regulations, and agreements. This includes construction, repair, and upgrade costs to meet new or more stringent environmental standards for all types of facilities and operations, such as wastewater and hazardous/solid wastes treatment/disposal, utility production, and Army family housing. The Environmental Compliance Program also includes limited roles in asbestos, radon, etc., as well as management of regulated medical, hazardous, radiological, and mixed wastes. MDEP VENC funds can be used for compliance-related equipment procurement, storage, and disposal; research and development; program management, salary, and training; permits and license costs; plans, studies, assessments, and audits; groundwater monitoring; laboratory analysis; and so forth.

Typically, VENC funding is restricted to projects that are currently out of compliance known as “Must Funds.” VENC funding is intended to support compliance with environmental laws and regulations and cannot be used to

- support any project not directly related to an environmental compliance requirement.
- perform routine range maintenance or modification or SRM responsibilities.
- support range operations related costs covered by VSCW.
- accomplish UXO removal or clearance operations.
- perform Army Conservation Program requirements, such as the PLS.

The installation proponent for VENC funding is the Environmental Office Chief. Project-level descriptions are submitted using the ECS Methodology through the installation environmental office and flow through the garrison chain of command to HQDA for funding. Range Officers must work with the garrison environmental office for VENC project funding.

Environmental Pollution Prevention Program (MDEP VEPP)

The Environmental P2 Program, MDEP VEPP, provides resources that focus on using prevention-based solutions as the preferred methods to achieve and/or sustain compliance with environmental laws, regulations, and executive orders. A P2 project applies source reduction, recycling, or waste minimization to reduce releases, wastes, pollution, and costs from an installation’s current business practices, industrial processes, base operations, or other routine and recurring sources of wastes, pollution, or releases to the environment (ref 64).

P2 program support includes procurement and installation of materials or processes; studies, plans, and assessments; acquisition and installation or retrofit of equipment; and costs of changing operating procedures. The P2 program promotes integration of environmental considerations and pollution protection into the system’s acquisition process.

VEPP funding is intended to support P2 initiatives and cannot be used to

- accomplish RCRA compliance projects that do not achieve process or future efficiency.
- correct maneuver damage on training land covered by ITAM LRAM funding.
- perform Army Conservation Program Stewardship requirements.
- support range operations related costs covered by VSCW.
- accomplish UXO removal or clearance operations.
- fund reimbursable environmental research and development at the lead organization or installation level funded under the Environmental Quality Technology Program MDEP VEQT.
- survey, monitor, and clean up historic or past contamination (asbestos, polychlorinated biphenyls (PCBs), lead-based paint, underground storage tank (UST) or aboveground storage tank (AST) removal, Defense Environmental Restoration Act (DERA) or RCRA solid waste management unit (SWMU) site cleanup).
- support spill prevention training, personnel, and supplies.
- accomplish environmental monitoring (including groundwater monitoring), whether or not required by regulation or compliance agreement.
- accomplish environmental compliance assessment.
- support storm water pollution management or prevention plans or mitigation

The installation proponent for VEPP funding is the Environmental Office Chief. Project-level descriptions are submitted using the ECS Methodology through the installation environmental office and flow through the garrison chain of command to HQDA for funding. Range Officers must work with the garrison environmental Office for VEPP project funding.

6.2.3 Range Conservation

Environmental Conservation Program (MDEP VENN)

The Environmental Conservation Program, MDEP VENN, funds legally driven costs for installation and tenant activity conservation of natural and cultural resources in accordance with laws, regulations, and agreements. This includes costs associated with performance of surveys, inventories, or assessments; preparation and execution of management plans with a legal environmental driver; cooperative agreements; and consultation with federal, state, local, and tribal entities. Typical areas of funding support include wildlife (including threatened and endangered species), limited ecosystem management, soil stabilization (compliance related), sediment reduction, architectural archeology inventories and evaluations, Steps I and II archeological collections, Federally recognized Native American consultation, National Historic Preservation Act (NHPA) and Native American Graves Protection and Repatriation Act (NAGPRA) agreement documents, and NHPA mitigation. For soil sustainment issues, VENN funds overall sustainment planning framework, routine natural resource maintenance in range complexes, rehabilitation necessary as a result of forces of nature, watershed protection measures, and prescribed fires.

VENN funding is intended to support Natural and Cultural Resources and cannot be used to

- perform routine range maintenance or modification or SRM responsibilities.
- correct maneuver damage on training land covered by ITAM LRAM funding.
- perform routine maintenance on historic buildings/structures.
- support range operations related costs covered by VSCW.
- fund reimbursable environmental research and development at the lead organization or installation level.
- cover costs associated with lack of maintenance resulting in an enforcement action or foreclosure.

The installation proponent for VENN funding is the Environmental Office Chief. Project-level descriptions are submitted using ECS Methodology through the installation environmental office and flow through the garrison chain of command to HQDA for funding. Range Officers must work with the garrison environmental office for VENN project funding.

Appendix A. Range Evaluation Checklists

TABLE A-1. WATERSHED AND BACKGROUND INFORMATION CHECKLIST

Required Information		Data Gathered/Where Documented	Manual Paragraph
Contour maps	Watershed delineation maps.		2.2.1
	Range area overlay.		
Soil	Soil classifications.		2.2.2
	Soil texture.		
	Erosion factors.		
	Permeability.		
	Available water capacity.		
	Soil texture of berm (if used on range).		
	Mineralogy and subsurface stratification.		
Groundwater	Depth to groundwater.		
	Aquifer characteristics beneath range (thickness, size, or areal extent).		
	Aquifer productivity and regulatory classification.		
	Direction of groundwater movement.		
	Location of potable water wells within 1/2 mile of range(s).		
	Potable water use information.		
	Surface seeps or discharge points (such as streams).		
Surface water	Surface water use information (regulatory classification).		
	Distance from range area to water resource.		
	Slope of the land between water resource and range.		
	Vegetation between water resource and range.		
	Storm water drainage systems that create a direct pathway from range to water resource (e.g., drainage pipes).		
	Other structures or activities that may impact water resource.		

TABLE A-1 (CONT'D)

Required Information		Data Gathered/Where Documented	Manual Paragraph
Climate	Rainfall data (2-year, 24-hour depth, monthly average depth. Estimated transport distribution of annual precipitation via evaporation/transpiration, runoff, and groundwater recharge).		
	Wind data (direction, monthly average speed, peak gust speed).		
	Temperature (monthly average, high and low).		
Geographical	Distance to installation boundary.		
	Distance to cantonment area.		
	Distance to other sensitive habits or areas of potential human exposure.		
Range type(s) and use	Range type.		
	Length of time ranges have been in use.		
	Historical and current munitions types used on range(s).		
	Historical and current munitions quantities used on the range(s).		
	Typical distribution of shooters across range firing lanes.		
	Current range maintenance procedures.		

TABLE A-2. RANGE CHECK CHECKLIST

Required Information	Range Observations	Recorded Data
Predominant small arms round impact locations	Location(s) with respect to individual ranges.	
	Location(s) within subwatershed.	
	Direct impact into surface water resources (stream, lake, wetland, etc.).	
Predominant small arms round condition at each impact location	Physical condition (intact, large fragments, dust-sized fragmentation).	
	Corrosion condition (presence of corrosion production on round or surrounding soil, color, easily removed or tightly adhering corrosion).	
Land/erosion characteristics at each impact location	Soil texture.	
	Slope (if berm is used, include berm dimensions).	
	Soil pH.	
	Surround vegetative cover (type, density, vigor).	
	Erosion evidence (small arms round and rainfall impact erosion, rills, gulleys, sediment deposition in surrounding area).	
	Storm water flow path delineation.	

TABLE A-2 (CONT'D)

Required Information	Range Observations	Recorded Data
Surface water proximity to each impact location	Distance to surface water source.	
	Surface water physical characteristics and stream health (if applicable).	
	Natural conditions between each impact location and surface water resource (erosion evidence, vegetation, riparian zones, bank stability, etc.).	
	Man-made structures between each impact location and surface water resource that may affect storm water flow paths or erosion characteristics.	
	Estimated groundwater proximity at each impact location; evidence of groundwater seeps between impact locations and surface water resources.	

Appendix B. Example Conceptual Site Model

The following is an example of a conceptual site model written for a portion of a small arms range training area. Not all background and range information is provided. This example is presented only to illustrate the level of detail included in the description of the environmental conditions at the range.

Small Arms Range Area Conceptual Site Model

A conceptual site model was developed as a brief and succinct description of the environmental conditions at the range area, as they are understood, combined with an evaluation of those conditions and the potential for environmental impact. The three subwatersheds in which the small arms ranges are located comprise 51.1 percent of the Alpha Creek watershed. The remaining portions of the Alpha Creek watershed consist of maneuver training areas (5.6 sq. mi.) and on- and off-post land (3.7 sq. mi.) through which interstate highway 77 crosses. The off-post area is used primarily for commercial and residential purposes (developed urban areas). Each subwatershed conceptual site model is presented below. The subwatershed information is presented in Table B-1.

Bravo Creek Subwatershed

The Bravo Creek subwatershed drains an area of 3.1 square miles and comprises 16.3 percent of the Alpha Creek watershed. Small arms fire from ranges 20, 1, 2, 3, and half of range 4 impact within this watershed. Approximately 2.9 million 5.56-mm rounds are fired into this area annually. These rounds are typically fired into berms on Ranges 1, 2, 3, and 4; however, dispersion of bullet fragments behind the berm occurs after the rounds impact the berms. In addition, rounds are frequently fired over the berms into the impact area. Rounds fired on Range 20 will impact either on the range or in the impact area depending on the elevation of the target with respect to the firing position. These firing and dispersion patterns yield a broad area of dispersion of bullet fragments within the subwatershed.

The REST analysis of corrosion within these range areas predicted low to very low potential for corrosion of the bullet debris; however, during range checks both surface and subsurface bullet debris was observed to have a buildup of corrosion products, indicating an aggressive corrosion environment. This may result in the formation of lead ions that may bond to soil particles or be mobilized in water that either infiltrates the soil or runs off the range.

Aerial transport of lead particles from lead contaminated soil is not believed to be a factor. The impact area and areas surrounding the ranges are heavily forested, thus providing natural windbreaks. No evidence of windblown sediment transport was observed during range checks. This corresponds to the REST predictions of low to very low potential for aerial transport.

TABLE B-1. STEP I - RANGE AREA, WATERSHEDS, AND FIRING DATA

Subwatershed	Land Area, sq. mi.	% of Total Watershed Area[a]	Ranges	REST Score	Rounds Fired, FY2000	Lead Mass, kg	Storm Water Control Structures[b]	Comments
Bravo Creek	3.1	16.3			2,868,700	5,949.7		
			1	3.7	410,000	850.3	No	
			2	5.5	440,000	912.6	No	Bravo Creek is within 20 to 30 ft of backside of impact berm, bullet fragments in creek bed.
			3	3.2	5,000	10.4	Partial	Heavy gullying in drainage immediately behind berm.
			4, south half	4.3	215,000	445.9	Yes	
			20	1.0	1,798,700	3,730.5	No	Water supply well on site.
Charlie Creek	2.1	11.1			4,467,100	9,264.8		
			4, north half	4.1	215,000	445.9	Yes	
			5	4.3	494,000	1,024.6	Yes	
			6	[c]-	[c]-	[c]-	No	
			7	4.3	242,000	501.9	No	
			8	4.3	331,000	686.5	No	Berm completely unvegetated, heavy soil erosion and sediment transport off range, water supply well for Ranges 1 through 9 near range.
			9	5.5	3,185,100	6,605.9	No	Largest range, heaviest training use, large unvegetated berm, heavy sediment transport off range.

See footnotes and legend at end of table.

TABLE B-1 (CONT'D)

Subwatershed	Land Area, sq. mi.	% of Total Watershed Area[a]	Ranges	REST Score	Rounds Fired, FY2000	Lead Mass, kg	Storm Water Control Structures[b]	Comments
Delta Creek	4.5	23.7			1,976,300	4,098.8		
			10	3.1	319,000	661.6	No	
			11	[c]-	[c]-	[c]-	Yes	
			12	5.1	1,657,300	3,437.2	Yes	
			13	[c]-	[c]-	[c]-	No	Heavy soil erosion and sediment transport but dispersion over flat area, range ownership in transition.
Other Areas	9.3	49.0	NA	NA	NA	NA	NA	
On Installation	5.6	29.5	NA	NA	NA	NA	NA	
Off Installation	3.7	19.5	NA	NA	NA	NA	NA	Mostly developed, urban areas.

[a]Alpha Creek watershed area is 19.0 square miles.
[b]Storm water control structures are defined as water detention or retention ponds that intercept runoff from impact berms.
[c]Range use data were not available.

FY = Fiscal year.
NA = Not applicable.
REST = Range Evaluation Software Tool.

The REST analysis predicted a medium to high potential of transport to groundwater for the area within this subwatershed. Soil cores taken during the installation of shallow (10- to 15-ft depths) monitoring wells on Range 2 showed the presence of clay confining units in two of the wells (MW-2 and MW-3). The third well (MW-1) encountered no interstitial clay layers. The entire soil profile was sand. The lead levels monitored in MW-2 and MW-3 reflected the impact of the clay confining units. Lead levels were elevated in both the total and dissolved phase in MW-1, while lead levels in MW-2 and MW-3 remained below the State maximum concentration limit (MCL). These variations in soil conditions are typical to these range areas. Considering the fact that lead is widely dispersed in the impact area, areas of varying shallow groundwater impact can be expected to be found throughout the ranges.

The primary transport mechanism for lead from the ranges appears to be surface water transport, specifically, storm water runoff. The REST analysis ranked the surface water transport potential for Range 20 as very low because of its distance from Bravo Creek and the heavy forest and vegetation between where the rounds are dispersed and Bravo Creek. Ranges 1, 2, 3, and 4 were ranked as medium to high by REST. Range checks supported this ranking. The hilly nature of the small arms range area, the use of steep sloped berms constructed from local soils, and the high sand content of the local soils, create conditions that are naturally susceptible to soil erosion. The berm (and usually the drainage path in front of each berm) on each range has no vegetation and shows evidence of significant erosion and sediment transport. Berm slopes (35 and 45^{o}) have significant rilling and erosion. These rills and erosion occur in areas outside of the primary bullet impact points, indicating an inherent instability of the berm soils at these slopes. Transport away from the berm appears to consist of soil particles as suspended solids in storm water. This transport continues until the storm water reaches areas where the flow slows enough to allow settling of the solids or through vegetated areas where the solids are filtered out. Visible trails of eroded soil are evident in these flow paths. Within the Bravo Creek subwatershed, the solids appeared to remain suspended in the storm water and enter the creek.

Charlie Creek Subwatershed

The Charlie Creek subwatershed drains an area of 2.1 square miles and comprises 11.1 percent of the Alpha Creek watershed. Small arms fire from ranges 5, 6, 7, 8, 9, and half of range 4 impact within this watershed. Approximately 4.5 million 5.56-mm rounds are fired into this area annually. The majority of these rounds (3.2 million) are fired on range 9 into berms; however, dispersion of bullet fragments behind the berm occurs after the rounds impact the berms. In addition, rounds are frequently fired over the berms into the impact area. These firing and dispersion patterns yield a broad area of dispersion of bullet fragments within the subwatershed.

The REST analysis in these range areas predicted a low potential for corrosion of the bullet debris; however, during range checks both surface and subsurface bullet debris was observed to have a buildup of corrosion products, indicating an aggressive corrosion environment. This may result in the formation of lead ions or compounds that may bond to soil particles or be mobilized in water that either infiltrates the soil or runs off the ranges.

Aerial transport of lead particles from lead contaminated soil is not believed to be a factor in these range areas. The impact area and areas surrounding the ranges are heavily forested, thus providing natural windbreaks. No evidence of windblown sediment transport was observed during range checks. This corresponds to the REST predictions of low to very low potential for aerial transport.

The REST analysis predicted a high potential of transport to groundwater for the area within this subwatershed. A potable water well located on range 8, which is screened within the aquifer, was not previously sampled for lead. Based on a generalized understanding of groundwater flow and the shallow well information presented for the Bravo Creek subwatershed, lead infiltration is a shallow groundwater phenomenon only, with the discharge of the shallow groundwater providing the base flow for the creek in the Charlie Creek subwatershed.

The primary transport mechanism for lead from the ranges in this watershed appears to be surface water transport, specifically, storm water runoff. The REST analysis ranked the surface water transport potential for the ranges in the Charlie Creek subwatershed as high, and range checks have supported this ranking. The hilly nature of the small arms range area and the use of steep sloped berms constructed from local soils, combined with the high sand content of the local soils, creates conditions that are naturally susceptible to soil erosion. The berm (and usually the drainage path in front of each berm) on each range has no vegetation and shows evidence of significant erosion and sediment transport. Berm slopes (35 and 45^{o}) have significant rilling and erosion. These rills and erosion occur even in areas outside of the primary bullet impact points, indicating an inherent instability of the berm soils at these slopes. Transport away from the berm appears to consist of soil particles suspended in storm water. This transport continues until the storm water reaches areas where its flow slows enough to allow settling of the solids or until it flows through vegetated areas where the solids are filtered out. Visible trails of eroded soil are evident in these flow paths. Within the Charlie Creek subwatershed, the solids appeared to remain suspended in the storm water and enter the creek.

Delta Creek Subwatershed

The Delta Creek subwatershed drains an area of 4.5 square miles and comprises 23.7 percent of the Alpha Creek watershed. Small arms fire from ranges 10, 11, 12, and 13 impact within this watershed. Approximately 2 million 5.56-mm rounds are fired into this area annually, the majority of which (1.7 million) are fired on range 12. These rounds are fired into a natural hillside. Because of the design of these ranges, there is a broad area of dispersion of bullet fragments on the hillside.

The REST analysis of corrosion within these range areas predicted a low potential for corrosion of the bullet debris; however, during range checks both surface and subsurface bullet debris was observed to have a buildup of corrosion products, indicating an aggressive corrosion environment. This may result in the formation of lead species that may bond to soil particles or be mobilized in water that either infiltrates into the soil or runs off the ranges.

Aerial transport of lead particles from lead contaminated soil is not believed to be significant. The impact area and areas surrounding the ranges are heavily forested, thus providing natural windbreaks. No evidence of windblown sediment transport was observed during range checks. This corresponds to the REST predictions of very low potential for aerial transport.

The REST analysis predicted a high potential of transport to groundwater for the area within this subwatershed. Based on the information previously presented, lead infiltration is a shallow groundwater phenomenon only, with the discharge of the shallow groundwater providing the base flow for the creek in the Delta Creek subwatershed.

The primary transport mechanism for lead from the ranges appears to be surface water transport, specifically, storm water runoff. The REST analysis ranked the surface water transport potential for the ranges in the Delta Creek subwatershed as high, and range checks have supported this ranking. The hilly nature of the small arms range area, combined with the high sand content of local soils, creates conditions that are naturally susceptible to soil erosion. The hillsides on each range have little vegetation and show evidence of significant erosion and sediment transport. Transport away from the hillsides appears to consist of soil particles as suspended solids in storm water. This transport continues until the storm water reaches areas where its flow slows enough to allow settling of the solids or until it flows through vegetated areas where the solids are filtered out. Visible trails of eroded soil are evident in these flow paths. Within the Delta Creek subwatershed, the solids appeared to remain suspended in the storm water and entered the creek.

Alpha Creek Watershed Overview

Currently, storm water runoff transport of eroded soils and lead residues poses the most significant environmental concern at the small arms ranges. There is visual evidence of significant soil erosion and sediment transport from the impact berms on many ranges, particularly Ranges 8 and 9 in the Charlie Creek subwatershed. All three subwatershed creeks discharge into Alpha Creek, which eventually flows off the installation. Much of the flow path of Alpha Creek is flat and marshy. A marshy area with slow water movement and a great deal of vegetation is a low-energy area conducive to the settling of sediments suspended in the water. Alpha Creek also discharges into a pond prior to leaving the installation. This is another low-energy area that should further reduce sediment loads by settling. Alpha Creek and the pond likely act as significant barriers or filters for suspended sediment loads that may be washing off the small arms range area. It is unlikely that significant off-installation transport of range pollutants will occur through this surface water pathway during moderate rainfall events. Historical data collected by the State Department of Health and Environmental Control (DHEC) (table B-2) (ref 67) supports this conclusion.

TABLE B-2. STATE DHEC RANGE AREA STORM WATER SAMPLING RESULTS

Date	Total Lead Concentration, ppb			
	Alpha Creek	**Bravo Creek**	**Charlie Creek**	**Delta Creek**
21 Nov 1994	[a]-	[a]-	1,100	[a]-
23 Jan 1995	< 50	[a]-	70	[a]-
8 Mar 1995	[a]-	360	[a]-	260
24 Apr 1995	< 50	[a]-	2,200	[a]-

[a]These locations were not sampled on these dates.

Because of the high sand content and acidic pH of local soils, it is likely that shallow groundwater under the range areas has been impacted. These range conditions represent a harsh environment that may be conducive to dissolving and transporting lead from bullet fragments into the shallow base flow that discharges into the three subwatershed creeks. This possibility is supported by the few rounds of shallow groundwater sampling performed at the wells on range 2 that showed high lead concentrations in the shallow groundwater immediately at range impact areas.

Deeper, regional groundwater flow in the surficial aquifer flows farther into the installation in a southeast-southerly direction, opposite the direction of surface water drainage in the small arms range area. Three rounds of sampling at the Gemini Lakes water supply wells by the State have not shown lead levels at or above the State MCL of 50.0 ppb. Two potable water supply wells for the ranges are in close proximity to the ranges and may represent a pathway for troops (human receptors) to be exposed to lead concentrations in the drinking water, but lead was not detected in samples collected in these wells.

Watershed, firing range, and range check data collected for the evaluation are shown in Table B-1. A review of these data suggests the Charlie Creek subwatershed has the highest potential for being impacted by small arms range operations and for having the highest concentrations or volumes of pollutant transport, as supported by the following:

- Charlie Creek is the smallest subwatershed, having the least amount of land area and containing the least amount of water.
- Charlie Creek subwatershed has the greatest number of ranges. The ranges represent a greater relative percent of the area of its subwatershed than the ranges in the other two subwatersheds.
- Charlie Creek subwatershed has the single largest range (range 9), with the single greatest input of lead.

- Charlie Creek subwatershed as a whole has the largest annual input of lead from firing.

- Charlie Creek subwatershed has two ranges (ranges 8 and 9) with the largest erosion and sediment transport problem, based on visual observations.

Of the two remaining subwatersheds, Bravo and Delta Creeks, the data from the conceptual site model suggest a vague ranking of the subwatersheds with regard to which subwatershed shows the next highest potential for off-range pollution transport concerns, and which shows the least. The Bravo Creek subwatershed may be considered to have a slightly higher potential for pollution transport and concentration concerns than Delta Creek. The Bravo Creek subwatershed has more ranges, a greater annual input of lead mass, less storm water management control structures, and a smaller land area than Delta Creek. This at least suggests that the ranges may be having a larger impact on the Bravo Creek subwatershed than on the Delta Creek subwatershed.

Appendix C. T_C Nomograph

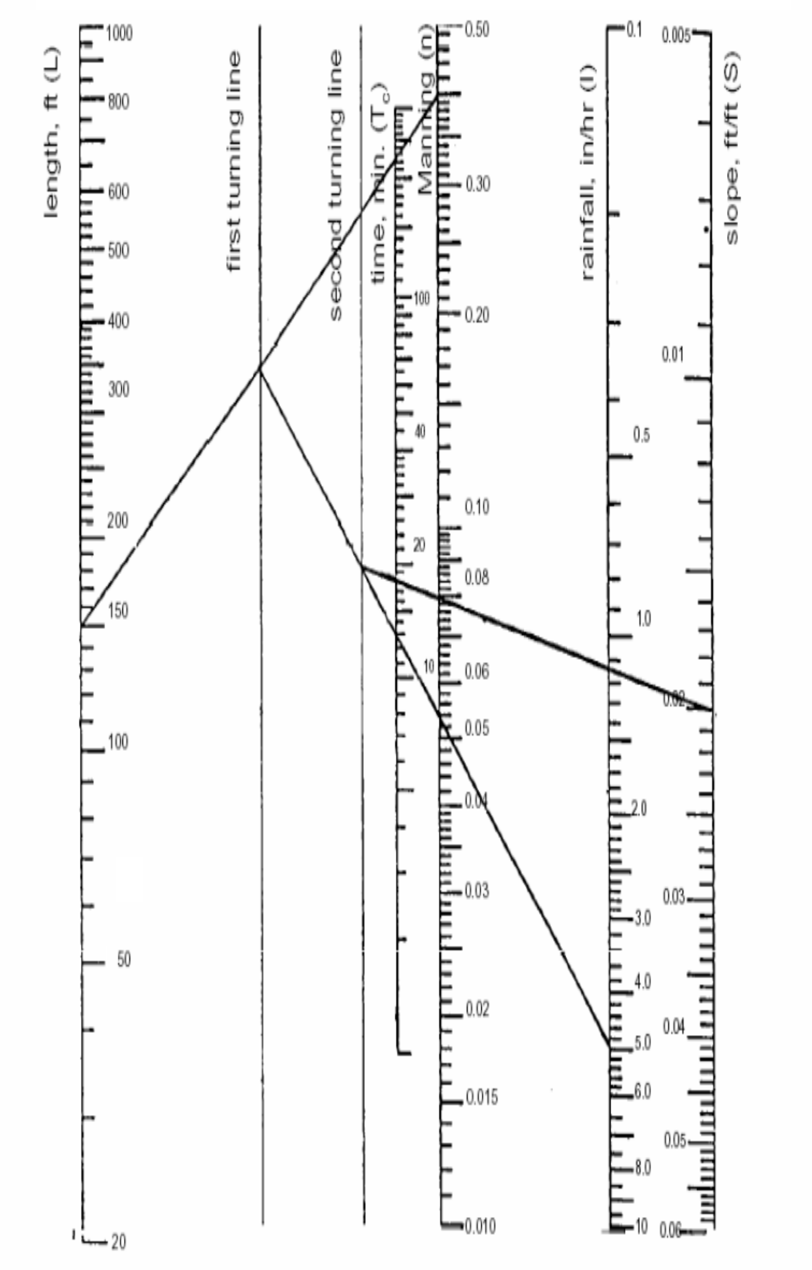


Figure C-1. Nomograph for determining T_C for overland flow, kinematic wave formulation (ref 68). (Source: Federal Highway Administration, 1979)

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Appendix E. Abbreviations

AC	= Active Component
ACSIM	= Assistant Chief of Staff for Installation Management
AFF	= Automated Field Fire
AMRP	= Army Master Range Plan
APPN	= appropriation
ARF	= Automated Record Fire
ARNG	= Army National Guard
ASAP	= Army Sampling and Analysis Plan
AST	= aboveground storage tank
ATC	= U.S. Army Aberdeen Test Center
ATEC	= U.S. Army Test and Evaluation Command
ATSC	= Army Training Support Center
ATTACC	= Army Training and Testing Area Carrying Capacity
BMP	= best management practice
CEC	= cation exchange capacity
CONUS	= Continental United States
CPQC	= Combat Pistol Qualification Course
CTC	= Combat Training Center
DAIM	= Department of the Army's Assistant Chief of Staff for Installation Management
DAMO-TRS	= Department of the Army Management Office - Training Simulations
DCSELE	= Deputy Chief of Staff for Engineering, Logistics, and Environment
DERA	= Defense Environmental Restoration Act
DHEC	= Department of Health and Environmental Control
DOP	= dioctyl phthalate
DPTM	= Directorate of Plans, Training, and Mobilization
DPW	= Department of Public Works
DTC	= U.S. Army Developmental Test Command
ECAM	= Environmental Cost Analysis Methodology
ECS	= EPR Cost Standardization
EPR	= Environmental Program Requirements
ERDC	= Engineer Research and Development Center
ERDC-CERL	= Engineer Research and Development Center - Construction Engineering and Research Laboratory
ERDC-CRREL	= Engineer Research and Development Center – Cold Regions Research and Engineering Laboratory
ERDC-EL	= Engineer Research and Development Center - Environmental Laboratory
ESTCP	= Environmental Security Technology Certification Program
FCC	= Facility Category Code
FY	= fiscal year
GIS	= Geographic Information Systems
HEPA	= high-efficiency particulate air

HNC	=	Huntsville Engineering Support Center
HQDA	=	Headquarters, Department of the Army
IFS	=	installation facility system
IMA	=	Installation Management Agency
ITAM	=	Integrated Training Area Management
ITRC	=	Interstate Technology and Regulatory Council
LRAM	=	Land Rehabilitation and Maintenance
MACOM	=	Major Army Command
MCA	=	Military Construction, Army
MCAR	=	Military Construction, Army Reserve
MCL	=	maximum concentration limit
MCNG	=	Military Construction, National Guard
MDEP	=	Management Decision Package
METDC	=	Military Environmental Demonstration Center
MILCON	=	military construction
MOUT	=	Military Operations in Urban Terrain
MRF	=	Modified Record Fire
MSLS	=	Missile Procurement
NAGPRA	=	Native American Graves Protection and Repatriation Act
NEPA	=	National Environmental Policy Act
NHPA	=	National Historic Preservation Act
NPK	=	nitrogen, phosphorous, potassium
NRCS	=	Natural Resources Conservation Service
O&M	=	operation and maintenance
OMA	=	operations and maintenance, Army
OMAR	=	operations and maintenance, Army Reserve
OMNG	=	operations and maintenance, National Guard
OPA3	=	Other Procurement, Army
P2	=	pollution prevention
PCB	=	polychlorinated biphenyls
PEG	=	Program Execution Group
PEO STAMIS	=	Program Executive Office, Standard Army Management Information Systems
PEO STRI	=	Program Executive Office Simulation Training and Instrumentation
POM	=	Program Objective Memorandum
PPBES	=	Planning, Programming, Budgeting, and Execution System
PPE	=	personal protective equipment
PLS	=	planning-level survey
Q	=	flow rate
QA	=	quality assurance
QC	=	quality control
QRPA	=	Real Property Maintenance
RCRA	=	Resource Conservation and Recovery Act
RDTE	=	research, development, test, and evaluation
RECCE	=	reconnaissance
REST	=	Range Evaluation Software Tool

RTLP	=	Range and Training Land Program
SACON	=	shock-absorbing concrete
SDZ	=	surface danger zone
SEDSPEC	=	Sediment and Erosion Control Planning, Design and SPECification Information and Guidance Tool
SRA	=	Sustainable Range Awareness
SRM	=	Sustainment, Revitalization & Maintenance
SRP	=	Sustainable Range Program
STRICOM	=	Simulation, Training, and Instrumentation Command
SWMU	=	solid waste management unit
T_C	=	time of concentration
TCLP	=	Toxicity Characteristic Leaching Procedure
TRADOC	=	Training and Doctrine Command
TRI	=	Training Requirements Integration
TSS	=	total suspended solids
USACE	=	U.S. Army Corps of Engineers
USAEC	=	U.S. Army Environmental Center
USAR	=	U.S. Army Reserve
USAREUR	=	U.S. Army, European Command
USARPAC	=	U.S. Army, Pacific Command
USDA	=	U.S. Department of Agriculture
USEPA	=	U.S. Environmental Protection Agency
USGS	=	U.S. Geological Survey
UST	=	underground storage tank
UXO	=	unexploded ordnance
WES	=	Waterways Experiment Station

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