United States Environmental Protection Agency | Office of Emergency and Remedial Response Washington, DC 20460 | EPA 540-K-01-002 OSWER 9230.0-93 March 2001

EPA

Reusing Cleaned Up Superfund Sites:

Recreational Use of Land Above Hazardous Waste Containment Areas

Notice

Table of Contents

Preface ii

Section 1. Introduction 1
- Purpose 1
- Organization of Report 2
- For More Information 3

Section 2. Background 4
- Cover Systems and Associated Remedial Activities 4
- Recreational Activities Compatible With Containment Systems 8
- Integrating Reuse Plans into Remedies 13

Section 3. Remedial Design Considerations for Recreational Reuse 16
- Settlement and Subsidence 17
- Managing Gases 20
- Surface Vegetation 22
- Storm Water Management 26
- Ensuring Cover System Integrity 27
- Other Design Considerations 29

Section 4. Operation and Maintenance 34

Section 5. Case Studies 36
- Timber Butte Youth Park, Butte Montana (Silver Bow Creek Superfund Site) 36
- Chisman Creek Superfund Site, Seaford, Virginia 38
- Ohio River Park Superfund Site, Neville Island, Pennsylvania 40

Bibliography 42

Appendix A. Size and Configuration of Sports Fields A-1

Appendix B. Information Sources for Recreational Reuse B-1

Appendix C. Superfund Recreational Reuse Sites and EPA Contacts C-1

Preface

As of February 2001, more than 190 cleaned up Superfund sites have been returned to productive use. Many of these sites have been developed into recreational facilities, such as sports fields, hiking trails, parks, playgrounds, and picnic areas. There are many other Superfund sites that may potentially be used for similar purposes after they are cleaned up. The U.S. Environmental Protection Agency (EPA), through programs such as the Superfund Redevelopment Initiative, promotes the productive reuse of Superfund sites. EPA's overriding objective for any Superfund site is to ensure it is safe and that public or private use does not compromise or adversely affect the performance of the remedy. Because land use is a local decision, EPA does not favor one type of reuse over another.

This report provides technical information on how sites with waste containment areas have been safely reused for recreational purposes while ensuring that the integrity and protectiveness of the remedy are maintained. This information may be helpful when considering recreational reuse options during EPA's process of selecting and designing a cleanup plan for a Superfund site. The information presented in this report draws on the experiences and lessons learned from previous recreational redevelopment projects on Superfund and other contaminated sites. This report is intended for informational purposes only and should not be considered as Agency policy or guidance.

This report is one of a series being developed under the Superfund Redevelopment Initiative to inform stakeholders at hazardous waste sites about how EPA considers reuse options in the remedy selection and design process. Other reports in this series provide technical information on the reuse of Superfund waste containment areas for golf courses, commercial and industrial facilities, and ecological resources.

Section 1. Introduction

Across the country, EPA is working with communities to safely return Superfund sites to productive use. Former landfills, abandoned hazardous waste dumps, and other contaminated properties are being transformed into such assets as office parks, retail and industrial centers, residential neighborhoods, wildlife areas, and recreational facilities. Of the more than 190 Superfund sites in use as of February 2001, approximately 50 are being used for recreational purposes, such as sports fields, hiking trails, parks, playgrounds, and picnic areas. EPA's experience suggests that sites where the cleanup involves containing the wastes on site are often well suited for recreational uses. The on-site containment of wastes often requires vegetated cover systems that, with minor modifications, are highly compatible with a wide variety of recreational uses.

It is the responsibility of communities to decide how they plan to reuse these formerly contaminated sites. It is EPA's responsibility to work with communities to identify the anticipated future land use for sites to ensure that the cleanup of contaminated properties protects human health and the environment. For sites where the cleanup has already occurred, EPA must ensure that any subsequent reuse of the site does not adversely affect the protectiveness of the remedy. Careful planning and community involvement in the remedy selection process, appropriate design and construction practices, and proper operation and maintenance of the cleanup all work together to ensure the performance and protectiveness of the remedy and successful reuse.

Purpose

This report is intended for site managers, communities, property owners and developers, and others with an interest in reusing Superfund sites for recreational purposes. A separate report has been developed to specifically address the reuse of sites as golf courses. The purpose of this report is to provide detailed information on the technical aspects of safely integrating the design of recreational facilities into Superfund cleanups where some or all of the hazardous wastes will be, or have been, contained on site. This report is not intended to address enforcement, cost recovery, or other non-engineering issues associated with the cleanup of Superfund sites.

The material presented in this report draws on EPA's experiences and lessons learned from previous recreational redevelopment projects on contaminated sites. This information should not be considered Agency policy or guidance. Those considering the recreational reuse of hazardous waste sites may find the information helpful in understanding how cleanup plans can be modified to safely reuse a Superfund site while maintaining the integrity of the cover system. Detailed and comprehensive information on the design of recreational facilities, however, is beyond the scope of this report.

Organization of Report

The remainder of the report provides information on hazardous waste containment systems and the technical issues that need to be addressed when those systems will support recreational activities. It is organized into the following sections:

- **Section 2** provides background information on cover systems and other common remedial activities at containment sites, the various types of recreational activities that can occur on a containment site, and considerations when integrating reuse plans into the cleanup process.

- **Section 3** identifies remedial design considerations that may need to be addressed to support recreational reuse, including:

  - Post-construction waste settlement and subsidence and methods that have been used to minimize these problems;
  - Methods for managing gases that form under containment systems;
  - Characteristics and selection of different types of surface vegetation to support recreational reuse;
  - Approaches for managing storm water drainage that accommodate both the functional needs of the containment system and the future recreational needs;
  - Methods for controlling and avoiding the accidental intrusion of the cover; and
  - Considerations for integrating recreation-related buildings, utilities, and paved surfaces into the cleanup design.

- **Section 4** provides information on operation and maintenance activities that may be needed to support the integrity of the containment system and the recreational activities.

- **Section 5** highlights several sites where EPA addressed the design issues associated with the reuse of the site for recreational purposes.

- **Appendices** provide additional information to assist those interested in the recreational reuse of sites, including:

  - Size and configuration specifications for numerous types of sports fields;
  - Additional sources of information on design and construction of recreational facilities; and

– EPA contacts at Superfund sites that are being reused for recreational purposes.

For More Information

EPA prepared this report as part of its Superfund Redevelopment Initiative. The Superfund Redevelopment Initiative reflects EPA's commitment to consider reasonably anticipated future land uses when making remedy decisions at Superfund hazardous waste sites. The safe and productive reuse of Superfund sites can provide significant benefits to the local communities, including:

- New employment opportunities, increased property values, and catalysts for additional redevelopment activities;
- New recreational areas in communities where the availability of land for such activities may be limited;
- Enhanced day-to-day attention to the site, which can result in improved maintenance of the remedy and continued protection of human health and the environment; and
- Improved aesthetic quality of the site through the creation of maintained recreational facilities as well as discouragement of illegal waste disposal and similar unwanted activities.

For more information on the Superfund Redevelopment Initiative, including current developments, pilot programs, tools and resources, and site-specific information and case studies, please visit the Superfund Redevelopment Initiative web site at

http://www.epa.gov/superfund/programs/recycle/

or contact:

John Harris
Office of Emergency and Remedial Response
U.S. Environmental Protection Agency
Mail Code 5204G
1200 Pennsylvania Avenue, N.W.
Washington, DC 20460
703-603-9075
harris.john@epa.gov

Section 2. Background

This section provides information on the types of cover systems that EPA commonly uses to contain wastes on site, as well as several remedial activities that are often undertaken in conjunction with, or to augment, a cover system remedy. In addition, the different types of recreational uses that are compatible with waste containment systems are discussed. The section concludes with EPA's process and timing for considering the anticipated future use of sites in the remedy selection process and limitations on funding activities that enhance the remedy.

Cover Systems and Associated Remedial Activities

There are numerous remedial technologies that can be used to clean up a Superfund site. The remedy that is appropriate for a given site depends on waste or contaminant characteristics, ability to implement, effectiveness, cost, and other factors. At many Superfund sites, the remedial action leaves waste or contaminants on-site in engineered containment systems. In many cases, these containment systems can support recreational activities following their construction if certain engineering controls and safety precautions are taken. Several remedial technologies are often utilized at the same site. For example, remediation of a site may require a cover system, a ground water collection and treatment system, and a diversion wall.

Cover Systems

At most Superfund containment sites, the principle objectives of the cover system are to: (1) protect the public from coming into contact with hazardous waste; (2) prevent the release of hazardous waste to the environment; and (3) minimize surface water infiltration into the waste. General design requirements are based on federal or state criteria (e.g., Resource Conservation and Recovery Act (RCRA) Subtitle C or Subtitle D closure requirements).[1] Cover systems typically utilize one or more of the following types of barriers:

- **Hydraulic barriers** use a low-permeability physical barrier to impede the downward migration of water. These multi-layered caps typically incorporate geomembranes, geosynthetic clay liners, compacted clay liners, or a combination of these as the hydraulic barrier or barriers. However, asphalt and other materials can also be used as a barrier. Currently multi-layered hydraulic barrier caps are the most common type of

[1] U.S. Environmental Protection Agency, Technical Guidance for RCRA/CERCLA Final Covers (under development).

cover systems and are typically thought of when reference is made to a "RCRA Subtitle C or Subtitle D" cover.

- **Capillary barriers** essentially exploit the suction potential differences between fine and coarse grained soils to limit the downward movement of water. A simple configuration of this type of cover system consists of a fine-grained soil (clay) located over a coarser grained soil (sand). Under unsaturated conditions the fine-grained clay holds water, preventing its movement to the lower coarse-grained sand. As the fine-grained layer approaches saturation it begins to release water to the lower coarser layer. Because of this, capillary barrier systems are intended for use in arid to semi-arid climates where unsaturated conditions prevail.

- **Evapotranspiration barriers** also are used predominantly in arid and semi-arid environments. This type of cover generally consists of a thick layer of relatively fine-grained soils which is capable of supporting vegetation. The soil layer inhibits downward water movement and serves as a storage reservoir that holds water until its future removal by evapotranspiration processes.

- **Direct contact barriers** provide a physical barrier against contaminants that are a contact and ingestion hazard. These covers are typically one to three feet deep, but can be deeper, and act as a contact barrier as well as provide some protection against erosion and shallow digging. Soil covers are often economical because they typically consist of soils or general fill covered with a few inches of topsoil to support vegetation. These types of covers are commonly used with metal or asbestos contamination, because these contaminants are less likely to migrate and contaminate the local environment.

- **Surface soil covers** provide a physical barrier against contaminants that are contact and ingestion hazards. These types of covers are often less than one foot deep and are constructed over contaminated soils that have been stabilized and are unlikely to migrate and contaminate the nearby environment. Because these covers are more susceptible to exposure from erosion or shallow digging, they are often vegetated and constructed in areas that are restricted or in areas that are monitored and well maintained.

- **Liners** are barriers, typically constructed in landfills, that prevent the migration of contaminants to the environment. The barrier prevents waste, leachate, and gases produced by the landfill from contaminating adjacent soil and groundwater. Liners often consist of clay or a geomembrane depending on local geology and environmental requirements.

Depending on site-specific requirements, cover systems can be composed of multiple layers of natural and synthetic materials for gas control, internal drainage, vegetative support, or other purposes. In some cases, individual layers serve dual purposes. When completing the construction of a cover system, the remedial project manager (RPM) may consider additional sampling to ensure that the cap is protective of future recreational reuse and that cross-media

contamination of cover or fill material has not occurred. A number of EPA guidance documents address cover system function and design, including:

- *Design and Construction of Covers for Solid Waste Landfills*,1979 (EPA 600/2-79/165);
- *Evaluating Cover Systems for Solid and Hazardous Waste*, 1980 (EPA 530/SW-867c);
- *Standardized Procedures for Planting Vegetation on Completed Sanitary Landfills*, 1983 (EPA 600/2-83/055);
- *Covers for Uncontrolled Hazardous Waste Sites*, 1985 (EPA 540/2-85/002);
- *Engineering Guidance for the Design, Construction, and Maintenance of Cover Systems for Hazardous Waste*, 1987 (EPA 600/2-87/039);
- *Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments*, 1989 (EPA 530/SW-89/047);
- *Seminar Publication: Design and Construction of RCRA/CERCLA Final Covers*, 1991 (EPA 625/4-91/025);
- *Presumptive Remedies: CERCLA Landfill Caps RI/FS Data Collection Guide*, 1995 (EPA 540/F-95/009); and
- *Technical Guidance for RCRA/CERCLA Final Covers* (expected 2001).[2]

<u>Associated Remedial Technologies</u>

There are several remedial technologies utilized at a site in conjunction with, or to augment, a cover system remedy. Because Superfund sites frequently have groundwater contamination, most of these technologies are for groundwater remediation. The following are some of the more common types of technologies associated with containment systems:

- **Groundwater pump-and-treat systems** typically consist of a number of extraction wells or french drains that collect contaminated groundwater for subsequent above-ground treatment. There are a number of variations of a typical groundwater pump-and-treat system that enhance performance or target multiple media (e.g., soil and groundwater). Dual phase extraction (DPE) is one such technique. DPE is a

[2] These documents are available from the Government Printing Office. Several of these documents are available online using EPA’s online search engine at www.epa.gov/epahome/search.html.

technology that uses pumps to remove various combinations of contaminated groundwater, separate-phase petroleum product, and hydrocarbon vapor from the subsurface. Whatever the remedial technology and media, all collection and treatment systems require piping, utilities, and on-site or off-site treatment systems in addition to the wells or drains. The need for and location of such facilities must be considered when developing reuse plans.

- **Diversion walls** are below-grade structures designed to divert uncontaminated groundwater flow away from contaminated material or to channel contaminated groundwater. Since these are below-ground features, they typically will not interfere with recreational site reuse. However, their presence needs to be taken into consideration so that they are not damaged by reuse activities.

- **Permeable reactive barriers (PRBs)** are both containment and treatment systems for contaminated groundwater. In such a system, reactive material is placed in a location to intercept contaminated groundwater. As the groundwater flows through the media, contaminants are "trapped" by the reactive material and treated water flows out the other side of the barrier. Since the reactive material may need to be replaced periodically, PRBs are placed in accessible locations. This may impact development options or the location of PRBs at reuse sites.

- **Landfill gas collection systems** are used to control the movement and prevent the buildup of harmful gases within a landfill. Two common types of collection systems used are passive and active. A passive gas collection system includes a series of vents that extend vertically through the cover, and as gas pressure builds within the landfill, that gas is forced outward through the vents. An active collection system uses a pump to create a negative pressure within the landfill to collect and move gases either vertically or horizontally to a discharge or treatment point. Collection systems can also be designed to recover the energy from gases and use it to power other applications.

- **Leachate collection systems** control the movement and prevent the buildup of leachate within a landfill. Leachate is produced when water percolates through solid wastes that are undergoing decomposition and both biological and chemical constituents leach into the water. The collection systems typically consist of soils with high hydraulic conductivity values (e.g., sand) and perforated pipes located between the waste and the bottom liner. Highly permeable soils will typically be graded with a 1 to 5 percent slope to help channel the leachate into trenches that contain the perforated pipes. Once the leachate is in the perforated pipe, either a downward slope or a pump is used to extract the liquid from the landfill.

- **Solidification and stabilization** involve modifying the physical or chemical properties of the waste to improve its engineering properties or leaching characteristics, or to decrease its toxicity. Solidification encapsulates contaminants into a solid material of high structural integrity. Stabilization converts waste contaminants into a less soluble, mobile, or toxic form. Some types of waste require solidification or stabilization prior to being placed into a landfill or covered by an engineered cover system.

Recreational Activities Compatible With Containment Systems

There is a wide variety of recreational activities that are compatible with waste containment systems. In many cases, a site that will be redeveloped for recreational purposes will support more than one type of recreational activity. For example, a site developed as a general use park may also accommodate sports fields, playgrounds, trails, or other recreational features. In other cases, recreation may be secondary to a primary use, such as a commercial development.

The following sections provide information on the types of recreational activities that can be supported at sites where waste is contained on site and identify a few of the more critical remedy design considerations for each activity. (EPA is preparing a report that specifically addresses technical considerations for integrating golf courses with waste containment remedies.) Whatever the type of recreational use a community prefers for a site, there are remedial design issues that are common to many containment systems that may be used, such as settlement, managing gases, and storm water drainage. Some types of waste containment areas may raise more design issues than others; for example, municipal landfills are more likely to have issues with settlement and managing the buildup of methane and other gases than non-landfill sites. Section 3 provides more detailed information on the engineering considerations when designing a remedy where a waste containment area will be used for recreational purposes.

Athletic Fields and Courts

Many sites with containment areas have been used to support a variety of athletic fields and courts, such as softball, baseball, soccer, football, volleyball and basketball. The choice of a remedy at a site that will support athletic fields will take into account a variety of design issues to ensure that the integrity of the remedy is maintained. For example, it is important when designing the cover system to take measures to ensure a proper slope and avoid subsidence, manage drainage and storm water runoff, and select an appropriate type of vegetative cover. These design issues are also affected by the specific types of activities anticipated for the site. For example, the remedial design will need to address issues of cap intrusion if reuse plans include such structures as concession stands, bleachers, and goal posts. Likewise, field drainage, turf, and irrigation requirements for sports fields that will support an intensive and competitive level of play may be much different from those fields that will not. The configuration of the site, remedy components, and other site features can also affect the size, layout, and orientation of sports fields. Appendix A provides information on standard field and court sizes, orientation, and other information, and Appendix B provides additional sources of information for designing and building sports fields.

A sports complex, including six baseball and soccer fields, were built over waste containment areas at the Lapari Landfill Superfund site in Mantua Township, New Jersey.

Playgrounds and Picnic Areas

Playgrounds can take many shapes and sizes and can range from a single swing set to an elaborate play area with slides, climbing structures, sand boxes, and other equipment. Many general use parks also have shelters, grills, benches, and other picnic type areas. As such, almost any Superfund site can accommodate some form of playground or picnic area. When planning a playground or picnic area, the proximity of landfill gas management vents (where gas buildup is a concern) to these public use areas may be one of the most important considerations. Other design issues include the foundation requirements for structures and their impact on cover system components and the potential for increased surface water infiltration from playgrounds that are surfaced with sand, gravel, shredded wood, or rubber chips.

In Bangor, Maine, the city expanded a park and built a playground on a portion of the Bangor Gas Works site.

Appendix B provides additional sources of information for designing and building parks, playgrounds, and picnic areas.

Trails

Trails can be incorporated into almost any redevelopment plan. There are several categories of trails, including those designed for fitness, hiking, biking, and equestrian uses. The material used to surface the trails will be dependent on the types of activities anticipated. In addition, for trails that may be vulnerable to erosion, a high visibility warning layer may be used to alert maintenance crews that the trail has degraded to a point that repairs are required.

Hikers walk along a trail that showcases artifacts from former smelting operations in Anaconda, Montana. The trail was built on Anaconda Smelter Superfund site and surrounds a golf course designed by Jack Nicklaus.

Other Recreational Activities

There are a variety of other activities that can be supported at general use parks and similar recreational areas. A few of these activities are briefly described below. This list is not intended to be exhaustive; EPA recognizes that there are many more activities that can be supported at containment sites. Communities can determine what activities are most appropriate for their needs.

- **Sledding.** Some containment areas, such as former landfills, have steep side slopes that could be used for toboggan or sled runs. Just about any slope can be used for this type of activity as long as there are limited obstructions. Obstacles such as gas vents may need to be isolated or protected to prevent injury to the user and to minimize damage to these features. Side slope drainage features such as channels, swells, and terraces, if utilized, may also limit sledding activities. In Evanston, Illinois, a suburb of Chicago, the city's parks department converted several landfills into parks. One of the converted landfills supports sledding and tobogganing on its slopes. The Dupage County Landfill Superfund site, also in Illinois, supports an inner tube run on its cover system's slopes during the winter.

- **Golf Driving Range**. Driving ranges can be constructed on a wide variety of sites with differing configurations and slope. A typical driving range with 35 tees is about 240 yards wide and 300 yards long and requires approximately 12.5 acres. However, the size can be reduced with fewer tees or with the use of netting to contain errant golf balls. Common remedial design considerations include managing cap penetration for

The foundation for the golf tees is constructed for the driving range that was built on top of the Kane & Lombard Street Superfund site in Baltimore, Maryland.

structures built on the containment area (e.g., the

offices, concessions, covered tee area) and locating gas vents away from the tee area or placing barriers around gas vents to protect them from activities on the site, such as motorized ball collection vehicles. Appendix B provides sources of information on driving range and golf course design and construction. At the Kane and Lombard Street Drums Superfund site in downtown Baltimore, Maryland, developers built a family-oriented golf driving range on top of a waste containment area.

- **Archery.** The typical open field archery range is on level ground and covers approximately five acres for 25 shooting stations. An archery range can easily be constructed without intruding on the containment system. Locating gas vents at the site may be an important design consideration if gas management is a component of the remedy.

- **Ice Skating.** Ice skating can be considered wherever water is available and safe ice conditions can be expected with reasonable regularity. Ice skating rinks generally require ice to be at least four inches thick to be safe for skaters. Facilities that support ice skating include both indoor and outdoor ice skating rinks and each presents different types of issues for containment systems.
  For indoor skating rinks, the remedial design issues are comparable to the placement of any building or structure on a containment system (e.g., settlement, foundations that penetrate the cap, or incorporating utility corridors). For outdoor ice rinks, the placement of ponds on top of containment systems presents special remedial design considerations to ensure the integrity of the cover system. For example, if the ice rink is seasonal, special care may be necessary to ensure that melting ice does not introduce water into the cover system. In addition, settlement of the containment system may affect the ice surface and place additional maintenance requirements on the site. At the Ohio River Park Superfund Site in Neville island, Pennsylvania, a sports complex was built over a former municipal and industrial waste landfill. The facility includes an indoor skating rink.

At the Ohio River Park Superfund site in Neville Island, Pennsylvania, a skating rink and other sports facilities were built over a former municipal and industrial waste landfill.

- **Other Field Games.** Cover systems that provide relatively large open spaces can support a wide range of field sports or games, such as ultimate frisbee, frisbee golf, cricket, and rugby, to name a few. As with all reuse activities, cover system features will need to be designed to accommodate the reuse while ensuring that it remains protective and that the recreational activities do not affect the integrity of the cover system.

Integrating Reuse Plans into Remedies

Consideration of Future Land Use

Identifying the reasonably anticipated future use of land is an important consideration in the Superfund cleanup process and is the first step for integrating reuse plans into a cleanup. The anticipated future land use helps EPA determine the appropriate extent of remediation because it affects the types and frequency of exposures that may occur to any residual contamination on the site. The process for identifying the reasonably anticipated future use of land begins during the Remedial Investigation/Feasability Study (RI/FS) stage of the Superfund cleanup. At this time, EPA conducts a reuse assessment, which typically identifies broad categories of potential reuse such as recreational or commercial. This assessment initiates the reuse planning process and lays the groundwork for integrating reuse into the cleanup plan.

As part of the reuse assessment process, EPA holds discussions with local land use planning authorities, appropriate local officials, and the public to understand the reasonably anticipated future uses of the land on which the Superfund site is located. In addition to local preferences for land use, EPA considers the views of other site stakeholders, such as the state and the PRP landowner. Based on these discussions, EPA develops remedial action objectives and identifies remedial alternatives that are consistent with the anticipated future land use.

If there is substantial agreement on the future use of the site, EPA may be able to select a remedy that supports that use and take certain measures to accommodate that future land use when designing the remedy. However, EPA must balance this preference for future land use with other technical and legal considerations provided in the Superfund law and its implementing regulations.[3] Specifically, EPA balances the requirements to treat principal threats, to use engineering controls such as containment for low level threats, to use institutional controls to supplement engineering controls, and to consider the use of innovative technologies. In addition, EPA must comply with other laws when they are “applicable or relevant and appropriate.”

[3] See section 300.430(a)(1)(iii) of the National Contingency Plan at 40 CFR Part 300.

EPA will select a remedy for a site based on the reasonably anticipated future use of land, the consideration of the technical and legal requirements, and the views of the community, the state, and the PRP landowner. Two general land use situations could result from EPA's remedy selection decision:

- The remedy achieves cleanup levels that allow the entire site, or a portion of the site, to be available for the reasonably anticipated future land use – in these cases, EPA will work within its legal authorities to support the community's preferences for reuse; or

- The remedy achieves cleanup levels that require a more restricted land use than the reasonably anticipated future land use – in these situations, the site will not support the community's preferences for reuse and possible alternatives, if any, need to be discussed.

For detailed information on how EPA considers land use in the remedy selection process, see EPA's "Land Use in the CERCLA Remedy Selection Process," EPA OSWER Directive No. 9355.7-04 (available online at http://www.epa.gov/swerosps/bf/ascii/land_use.txt).

Timing

The future use of a Superfund site can affect all aspects of EPA's cleanup process from the RI/FS, through remedy selection, to remedy design and implementation. Consequently, communities are able to initiate reuse planning early in EPA's cleanup process to allow for an evaluation of the appropriate types of remediation and redevelopment options. The longer the community delays its reuse planning, the greater the possibility that some reuse scenarios will be eliminated due to remedy decisions that have already been made.

As discussed in the previous section, EPA conducts reuse assessments early in the RI/FS stage of the cleanup. However, the generalized use categories from a reuse assessment may not provide sufficient detail to guide the design or implementation of the remedy. To provide specific and detailed proposals for how a property may be used after cleanup, communities often develop more specific reuse plans after the RI/FS and prior to or as part of remedial design.

Many cleaned up Superfund sites currently do not support any type of reuse activity. However, EPA expects that a number of these sites may eventually be returned to productive use. Where waste is left on-site at levels that would require limited use and restricted exposure, EPA will conduct reviews at least every five years to monitor the site for any changes. Should land use change, it will be necessary to evaluate the implications of that change for the selected remedy, and whether the remedy remains protective.

In many cases, a remedy as designed and constructed may not be able to accommodate the planned use without modification. In some instances, the preferred reuse may not be feasible due to technical, legal, or other factors. If landowners or others decide at a future date to change the land use in a way that makes further cleanup necessary to ensure protectiveness, EPA does not

prevent them from conducting such a cleanup so long as protectiveness of the remedy is not compromised. Retrofitting an existing remedy to support reuse, or an alternative type of reuse at the site, requires careful planning, design, coordination with, and approval by, EPA and other regulatory agencies. As discussed below, EPA cannot fund, nor can it require PRPs or others to fund, activities that are considered enhancements to the remedy.

Enhancements

In general terms, features or modifications that accommodate redevelopment at a Superfund site and increase the cost of the remedy but are not required for its implementation are considered "betterments" or enhancements. Enhancements can include roads and parking lots, utility infrastructure, or athletic field lighting if they are required solely to support the planned future use. Construction of enhancements are beyond EPA's legal authority and, therefore, cannot be financed using EPA funds nor can EPA require a PRP to pay for the enhancements. Although they cannot be funded by EPA, enhancements can be included in the remedial action if they are consistent, and do not conflict, with the selected remedy and if the cost is covered by another party, such as the local government, a developer, the landowner, or a PRP.

In some cases, features of the remedy are modified for the proposed future use of the site, but their implementation does not increase the cost of the remedial action. As such, the feature is not considered an enhancement and may be eligible for EPA funding as part of a remedial action at a Fund-financed site. For example, substituting a turf grass for a native grass as the vegetation component of a cover system at an equal cost may not be considered an enhancement. Similarly, alterations to site grading to accommodate reuse may not be considered an enhancement so long as the cost for the modified grading does not exceed what the grading cost would have been absent reuse. Determining whether an activity constitutes an enhancement is performed on a site-specific basis.

Section 3.
Remedial Design Considerations for Recreational Reuse

A containment remedy, such as a cover system, can consist of multiple features and components that each have their own design constraints and criteria. These may be based on federal, state, and local regulatory requirements, national and local building codes, and site-specific considerations. For example, regulations may dictate the type and minimum thicknesses of materials used in a cover system. Site-specific considerations, such as depth of burial and external loading, may dictate the wall thickness of underground piping. Working within these design constraints and criteria, containment remedies often can accommodate the reuse of the site for recreational or other purposes.

When designing a containment remedy that will be reused for recreational purposes, several engineering and other technical considerations need to be addressed. Two issues that may have a profound effect at redevelopment sites are settlement and the management of gases that may form underneath the cover system. If not properly accounted for in the remedial design, these two issues can have a detrimental impact on the reuse activity. For instance, differential settlement (i.e., where the cap settles more in some places than in others) can result in an uneven surface area and make athletic fields unusable, and waste off-gases can pose health and safety concerns to site users. These considerations may be applicable at some sites and not at others; for example, at former landfill sites, issues such as gas collection, grading of slopes, and subsidence are more likely to arise than at non-landfill containment areas. Other design considerations include surface vegetation, storm water management, managing the penetration of the cap, avoiding accidental intrusion, and the on-site construction of paved surfaces, buildings, and utilities. Some of these considerations may be considered enhancements and may not be authorized or funded under CERCLA or the NCP. At non-reuse sites, these technical considerations may not be as critical because there is limited or no public access to the facility and no activity to support.

This section provides information on the design considerations that are addressed when preparing a waste containment area for recreational reuse. The information provided below is based on EPA's experience at Superfund and other waste sites and is not intended to serve as policy or guidance. As appropriate, EPA may conduct any necessary sampling to ensure that the site is able to safely support recreational reuse upon completion of the remedy.

Settlement and Subsidence

Exhibit 3-1
EPA Guidance on Settlement and Cover System Subsidence

- *Covers for Uncontrolled Hazardous Waste Sites*, 1985 (EPA 540/2-85/002)
- *Prediction/Mitigation of Subsidence Damage to Hazardous Waste Landfill Covers*, 1987 (EPA 600/2-87/025)
- *Seminar Publication: Design and Construction of RCRA/CERCLA Final Covers*, 1991 (EPA 625/4-91/025)
- *Technical Guidance for RCRA/CERCLA Final Covers* (planned 2001).

Cover system settlement is an issue that may need to be addressed during the design of remedies that will support recreational reuse, particularly at former landfill sites that may experience significant subsidence and differential settlements. Site-wide settlement can result in slopes that are too shallow or steep for proper function of the cover system and may inhibit recreational use of the facility. Localized differential settlement can cause depressions, holes, and cracks in playing surfaces and accompanying support areas (e.g., parking lots). It can also cause breaks in irrigation and process piping, disruption of gas collection systems and other system components, misalignment of fences and light posts, and damage to structures, which can render fields or supporting facilities unsafe for use and require costly repairs. However, if properly accounted for during reuse planning, design, construction, and operation and maintenance (O&M), cover system subsidence does not preclude the use of a site for recreational purposes. **Exhibit 3-1** identifies the principal EPA guidance documents that address settlement and subsidence at hazardous waste landfills.

Cover system settlement is due to the consolidation of underlying materials by several processes. These processes include the compression of materials under their own weight and the weight of any overlying materials or loads, chemical and biological degradation, raveling, and other mechanisms. The magnitude, distribution, and rate of settlement are governed by a number of factors including material age, type, density and thickness, loadings, and moisture conditions. In general, cover systems placed on older abandoned dumps, industrial waste sites, ash fill sites, and landfills experience greater total settlements than those constructed on newer landfills of similar size and waste type. This is primarily due to changes in disposal practices. Current practices generally result in a well-compacted waste mass free of highly compressible materials, drums, or other voids. Most Superfund landfill sites were created using older disposal practices and there is the potential for significant general subsidence and differential settlement of cover systems constructed on such sites.

An estimate of the rate, magnitude, and areal distribution of site settlement is usually performed to facilitate remedy design and reuse planning. An evaluation of the potential for localized differential settlement from mechanisms such as the collapse of buried drums can also be performed. Accurately estimating the magnitude and rate of waste consolidation and the corresponding settlement of cover systems or other structures can be difficult, particularly at sites where there is a large degree of subsurface heterogeneity, or where little is known about waste type and distribution. In some cases, it may be desirable to monitor the waste through the use of settlement gauges or survey monuments prior to and during design in order to improve the accuracy of settlement estimates. However, this approach usually requires an extended period of time before sufficient data is available on which to base an analysis. Consequently, if this type of monitoring is warranted, initiating it early in the Superfund process, such as during the remedial investigation stage, may be appropriate. Field and laboratory load tests may also be performed for similar purposes. The cost, time requirements, and usefulness of the collected data are considered when evaluating the need for such testing.

When considering reuse alternatives for a waste containment area, a community's reuse planners often factor settlement issues into their plans. In some cases, cover system subsidence may be adequately addressed through routine maintenance and design modifications or other constraints may not be necessary. One possible approach at sites that are expected to experience substantial settlement is to phase the development of the recreational areas.[4] With this approach, areas with acceptable levels of subsidence are initially developed, while development in other areas are delayed until excessive subsidence is no longer a concern. For example, a cover system that will experience significant settlement may be left undeveloped in the short-term, while the areas surrounding the cap are used as a park. The long-term reuse plans may provide for the development of soccer fields on the cover system after settlement is no longer a concern. In another case, a site may be better suited for a low-intensity use, such as a golf driving range, rather than a sports field, until a point in the future when further cover system subsidence is within an acceptable range.

It may also be possible to reduce future consolidation of the waste and corresponding settlements to acceptable levels during the construction phase of the project through a variety of techniques. These techniques include cover system reinforcement, soil/waste improvement (e.g., densification), and grade modifications. For example, cover system reinforcement was used at a municipal waste landfill in Elmhurst, Illinois, where the landfill cover was retrofitted with geogrid reinforcement because settlement was creating depressions in ball fields developed on the cover. The geogrids bridge voids or depressions that might develop below the athletic fields.[5] At the McColl Superfund site in Fullerton, California, geogrids were also incorporated into the cover system to minimize the formation of localized depressions that would otherwise limit the site's use as a golf course.[6]

---

[4] M. Golden, "Pros and Cons of Developing Recreational Facilities on Closed Landfills." International Conference on Marinas, Parks, and Recreation Developments, (1993): 257-260; and R.E. Mackey, "Three End-Uses for Closed Landfills and Their Impact on the Geosynthetic Design." Geotextiles and Geomembranes, 14 (1996): 409-424.

[5] S. Paukstis, "Landfill Transformed into Recreation Area." American City & County June 1993: 30.

[6] P. Collins, "Superfund Success, Superfast." Civil Engineering December 1998.

At the McColl Superfund site in Fullerton, California, a geogrid-reinforced cap was used to prevent depressions resulting from settlement. This former refinery waste dumping ground is now being used to extend an existing golf course.

Pre-loading, one method of densifying soil or waste with a temporary surcharge (e.g., soil embankment), was successfully used at a municipal waste landfill in Massachusetts to prepare the site for use as a park facility.[7] Dynamic compaction, another densification method which involves compressing the waste by dropping a heavy weight from a crane, was used in conjunction with pre-loading and pilings at the Raymark Industries Superfund site in Fairfield County, Connecticut, to prepare it for reuse as retail development. Dynamic compaction may not be possible at certain sites with unknown wastes due to worker safety concerns.[8] These types of waste consolidation techniques help ensure the continued protectiveness of the cover system in addition to facilitating the reuse of the site.

Grade modification is another design method that is commonly used to accommodate settlement. In order to meet minimum regulatory post settlement grades, which is typically three to five percent, cover systems are commonly constructed at steeper angles than required with the expectation that the slopes

[7] J. Kissida et al., "Landfill Park: From Eyesore to Asset." Civil Engineering (August 1991): 49-51.

[8] T. Naber, "Today's Landfill is Tomorrow's Playground." Waste Age (September 1987), 46-58; and R.M. Koerner and D.E. Daniel, Final Covers for Solid Waste Landfills and Abandoned Dumps (Reston, Virginia: American Society of Civil Engineers, 1997).

will flatten over time as the underlying waste consolidates. At recreational facilities a slight modification to this procedure may be appropriate. The surface of the cover system could be constructed to make the relatively flat slopes conducive to the reuse activity, while the underlying layers (e.g., drainage layer) are built at a steeper slope to accommodate settlement and satisfy regulatory requirements. As the cover system settles, additional fill can be placed on the surface to maintain the desired slope without impacting the performance of underlying layers.

A soccer field built on a portion of the Fairfax County Municipal Landfill in Virginia illustrates the need to address settlement, which can cause depressions in the cap that can lead to drainage problems and poor field conditions.

Managing Gases

Containment sites, depending on their composition and other factors, have the potential to generate significant quantities of gas. If not properly controlled, gases can damage cover system components, stress vegetation, create potential explosive conditions, and pose other health and safety concerns. Gas control is important at many containment sites, particularly former landfills, and added emphasis and caution are important when these sites are used for recreational purposes due to the close proximity to, and heavy use by, the public. At some waste containment sites, gas management is not an issue and, therefore, does not affect the reuse of the site.

The quantity, rate, and type of gas that a landfill or other containment site will generate depends on the composition, age, and volume of the waste, moisture conditions, and other factors. Municipal waste landfill off-gases generally consist of approximately 50 percent methane, 40 percent carbon monoxide, and 10 percent other compounds including nitrogen and sulfur.[9] Off-gases from municipal and other types of landfills or containment sites may also contain volatile organic compounds such as benzene, toluene, trichloroethylene, vinyl chloride, or other chemicals. Where appropriate, these gases are collected using either an active or passive strategy. An active collection system utilizes induced negative pressure (vacuum) to move gases to the discharge or treatment point, whereas passive systems rely on natural pressure gradients.

The need for, and the appropriate type and configuration of, a collection system (e.g., collection layers, wells, vents) depends on a number of factors including gas generation rates, gas composition, waste

[9] U.S. EPA, Seminar Publication: Design and Construction of RCRA/CERCLA Final Covers, 1991 (EPA 625/4-91/025).

thickness, depth to groundwater, and cover system components. The type of reuse also may be a factor in determining the appropriate type of system. Where collection systems are necessary, the design takes into account issues such as odor management, ignition sources, vent locations, treatment system location, discharge limitations, and the proximity of features to the public, all of which have added importance at sites used for recreational purposes.

A typical passive gas collection system includes a series of vents that extend through the cover system and discharge gases to the atmosphere. Similarly, an active system generally has a number of extraction wells that extend through the cover and connect to subsurface collection piping that transports the gas to a treatment facility or discharge point. When designing the gas collection system, particular attention is given to the type and concentration of gases that will be vented and the possible health and safety impacts to site users. Special consideration is given to the locations of vents, collection wells, piping, discharge points, and treatment systems and their proximity to site users. These types of features can be placed in areas that will not interfere with recreational activities and supporting facilities, and minimize distractions to recreational users and spectators from equipment noise, odors, or other factors (e.g., flares). In addition, the need for security measures beyond those normally required could be assessed to address the visibility and accessibility of these features to the public, and the increased potential for trespassing and vandalism. For instance, in addition to other security measures, facilities may be screened with vegetation to decrease their visibility and limit access.

Closed structures that support recreational areas, such as concession stands or maintenance facilities, pose additional gas control concerns. Due to their susceptibility to gas accumulation, these types of structures may require collection or monitoring systems that are independent of any other such systems at the site. Methods used to minimize gas intrusion into closed structures include constructing floor slabs with convex shaped bottoms, placing impermeable geomembranes below or within floors of structures, connecting services (sewer, gas, and electric) outside of the structure so they do not penetrate the floor slab and create avenues for gas infiltration, and installing vented crawl spaces.[10]

There are several sites where gas control systems were designed to accommodate reuse. At the Clark Tailings Operable Unit of the Silver Bow Creek Superfund Site, passive gas vents for a closed municipal landfill area are being located away from the tee boxes at this future golf driving range. Designers of the driving range also intend to disguise the gas vents as distance markers for golfers. At the Army Creek Landfill, an ecological reuse site, shrubbery was used to conceal gas vents and to provide a food source for animals. Horizontally installed gas collection systems have also been used to support reuse. At the Delaware Sand and Gravel site, a horizontal passive gas collection system was used to avoid vent protrusions into an overlying equipment storage area. The horizontal collection pipes discharge in an unused and unobstructed five acre area of the property.[11] A similar horizontal

[10] J.R. Emberton, and A. Parker, "The Problems Associated with Building on Landfill Sites." Waste Management & Research, 5 (1987): 473-482.

[11] U.S. EPA, Reuse of CERCLA Landfill and Containment Sites, 1999 (EPA/540-F-99-015).

collection system was used for an agricultural area established over a nine-acre municipal landfill site to minimize obstructions to tilling. The gas is passively discharged into perimeter ditches that are also used for drainage purposes to prevent stress on crops.[12]

Surface Vegetation

The vegetation used on cover systems serves several purposes, including limiting erosion of the underlying soil and promoting evapotranspiration of water. The appropriate or allowable vegetation for a given site depends on a number of factors, including the site's geographical location, the type of cover system that is selected, the planned future use, and any special accommodations that are made, such as irrigation. Although the type of vegetation that is used may change, the basic functions of the vegetative layer will remain the same. In arid or semi-arid areas of the country where a vegetative layer may not be used, recreational reuse with supporting systems may make vegetation a viable alternative to armored or other surface treatments. **Exhibit 3-2** delineates climate regions in the United States.

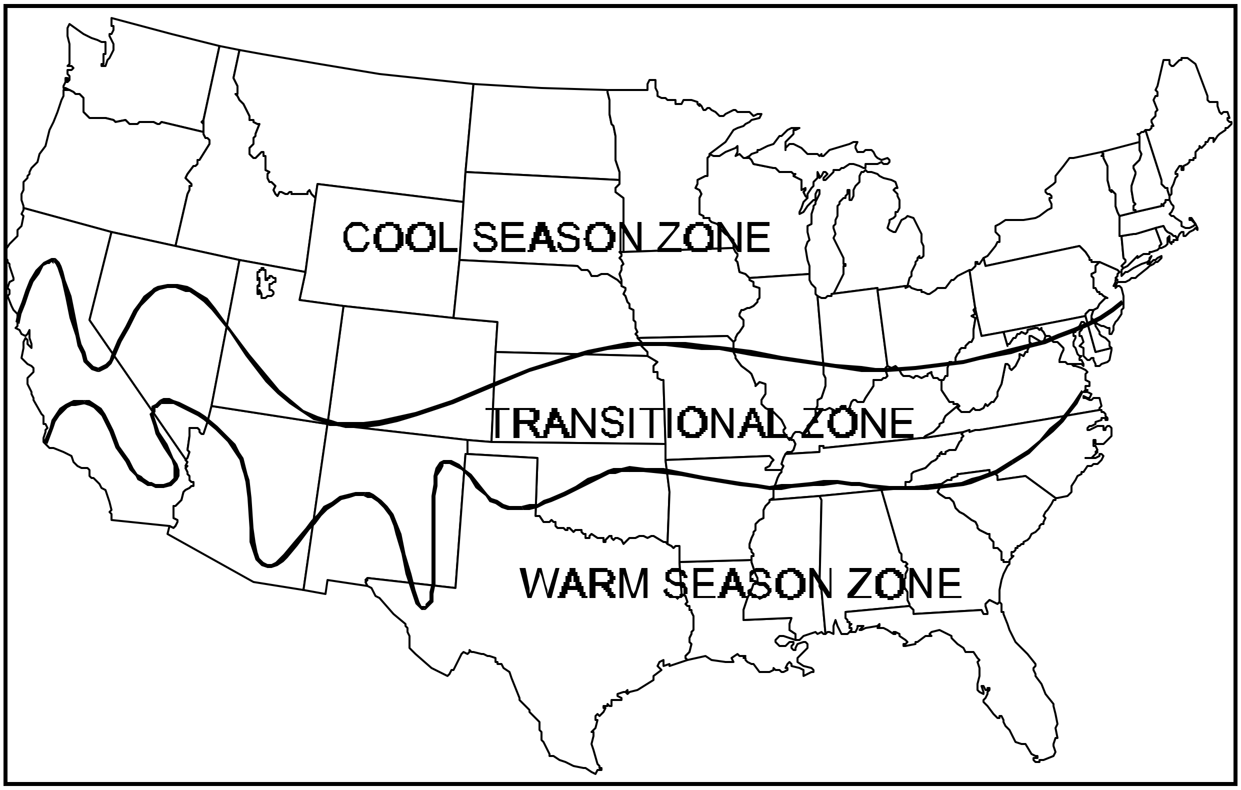
Historically, the preferred vegetation on cover systems has been a mixture of native grasses. Grasses are typically used because they have relatively shallow root systems, they minimize erosion, are well adapted to the local environment, and are capable of thriving with limited or no support (e.g., irrigation and fertilization). Trees, shrubs, and other deep rooted vegetation typically have not been used because of the potential for damage to critical cover system components from root intrusion, the possibility that roots could extend directly into waste, and other maintenance issues. Historically, landscaping features such as ponds have not been constructed on cover systems because of the potential for harmful impact on the performance of the remedy. However, if properly accounted for in planning and design, a Superfund site can support a wide variety of vegetation and landscaping features that protect the integrity of the remedy and improve a site's aesthetic qualities, and satisfy recreational needs.

Sports Fields

For cover systems designed to support sports fields, turf grass may be a better choice than native grasses. Turf grasses, such as Kentucky Blue Grass and Bermuda Grass, have been specially developed and selected to resist damage from foot traffic and grow quickly. Typically, a mixture of different turf grasses with varying levels of resistance to drought, temperature, disease, and other environmental factors are used for recreational fields. At the Chisman Creek Superfund site in York County, Virginia, softball fields were constructed on the cover over contaminated fly ash material. A combination of Kentucky bluegrass and tall fescue was used for the vegetative cover. This grass combination gave the fields durability during seasonal play and times of

[12] W.J. Spreull, and S. Cullum, "Landfill Gas Venting for Agricultural Restoration." Waste Management & Research, 5 (1986): 1-12.

Exhibit 3-2: Climate Regions of the United States



drought. Sod was applied to expedite the availability of the fields, as tall fescue takes a longer time to establish itself than other varieties of turf grass. **Exhibit 3-3** provides information on four commonly used turf grasses.

The surface layer of containment systems typically consists of topsoils that can accommodate a variety of recreational reuse activities. The surface layer of topsoil that supports turf grass or other vegetation used on a recreational field must be able to resist compaction from sports and other activities. A suitable topsoil for recreational fields consists of a well-screened (i.e., free of stones and other debris) sandy loam of uniform composition that contains a minimum of one percent organic matter and has a pH of 6.5 to 7.[13] Fields that are overly sandy need extensive irrigation and fertilizing, while soils with a high clay content drain poorly and compact easily, making it difficult to grow grass. To reduce the effect of compaction, many professional fields are constructed with a topsoil layer consisting of 80 to 85 percent sand.[14]

[13] J. Puhalla, Sports Field Design and Construction (Michigan: Ann Arbor Press,1999); and Prince William County, Design Standards (1996).

[14] Soccer Industry Council of America, Soccer Planning System: A Guide for Community Soccer Center Management (1998).

Exhibit 3-3: Characteristics of Common Turf Grasses			
Turf Grass Species	**Strength as Sports Turf**	**Limitation as Sports Turf**	**Comments**
Bermuda-grass	Robust vegetative growth, excellent wear resistance, good surface resiliency.	Limited to warm climatic regions of U.S., vegetative propagation only of improved types, slow establishment from seeded types.	Good for all sports fields, but cannot withstand heavy traffic during periods of dormancy (in cold weather).
Kentucky bluegrass	Robust vegetative growth, moderate wear resistance, good surface resiliency.	Limited to cool climatic regions of the U.S., slow establishment from seed.	Good for baseball, football, soccer fields. Most fields planted with mixture of Kentucky bluegrass and Perennial ryegrass.
Tall fescue	Excellent wear resistance, robust primary and vegetative growth, good surface resiliency, adapted to transition zone of the U.S.	Limited to transition or warmer regions of the U.S., poor sod knitting. Takes a long time to establish and has a tendency to become uneven and clumpy.	Good for baseball, football, soccer fields. Suggested for areas with a low annual rainfall.
Perennial ryegrass	Excellent wear resistance, robust primary and vegetative growth, prolific tillering, rapid seedling growth.	Limited to cool regions of the U.S., very poor sod knitting.	Good for baseball, football, soccer fields. Most fields planted with mixture of Kentucky bluegrass and Perennial ryegrass.

Adapted from J. Puhalla, Sports Field Design and Construction (1999).

As with any vegetative cover, it is important to select a grass species that will thrive in a particular region, thereby preventing erosion, protecting the cover, and supporting the intended post use. Technical assistance on selecting turf grass is available through the National Turfgrass Evaluation Program (go to http://www.ntep.org), which maintains a national database on success rate of seed mixes used throughout the country. Additional regional information can be obtained from the Natural Resources Conservation Service (NRCS) (go to http://www.nrcs.usda.gov/ NRCSorg.html). NRCS offices also profile information on native grass species and may be helpful in choosing a final turf grass mixture. Local nurseries and local parks departments can also provide useful information on turf grass selection.

Landscaping

At the McColl Superfund site in Fullerton, California, designers included landscaped areas as part of a golf course built over a cover system. Designers omitted a layer of cobbles for covers over landscaped areas to minimize settlement caused by the weight of the cap, using institutional controls instead.

In addition to the cover system, the overall landscaping scheme for the site will be considered during initial planning. For example, the cover system portion of the site may be vegetated with turf grass to accommodate athletic fields while the surrounding areas are planted with a variety of native grasses, trees, and shrubs for aesthetic purposes. Specially designed planting zones, islands, or terraces may be located within the limits of the cover system to support alternative vegetation. These areas may require thicker layers of supporting soils, biota barriers, enhanced drainage features, or other modifications to ensure that the integrity of the cover system is maintained and that function is not compromised. At the Clark Tailings Operable Unit of the Silver Bow Creek Superfund site, for example, soil berms were used to allow the planting of both coniferous and deciduous trees. Aboveground planters or similar structures may also be used to accommodate trees, shrubs, flowers, and other types of vegetation to some extent. Although some waste containment sites are able to support water-holding features such as lakes and ponds, such features are closely evaluated for their potential to increase the amount of water that infiltrates to the waste mass. Ponds and wetlands are commonly constructed outside of the limits of cover systems for aesthetic and storm water management purposes.

An important aspect to consider when developing landscaping plans is the level of short and long-term maintenance that will be required. As previously noted, one reason native grasses are used on most cover systems is that the maintenance requirements are relatively minimal. Additional maintenance efforts may be necessary at reuse sites depending on the vegetation and landscaping features. For example, additional and recurring costs can be incurred for fertilization, irrigation, pruning, trimming, and plant replacement. The cost for this type of maintenance will ultimately be borne by the local community or other parties responsible for maintaining the site depending on how site-specific agreements are fashioned.

Additional information on vegetation and ecological reuse of Superfund sites is provided in EPA's report *Reusing Cleaned Up Superfund Sites: Ecological Use of Land Above Hazardous Waste Containment Areas* (planned for 2001).

Storm Water Management

The manner in which storm water is managed will affect the design of a cover system and will strongly influence the performance of the cap, particularly with respect to erosion and stability. Methods for managing storm water on cover systems typically involve grading the cap to establish an effective slope, or constructing drainage channels and swales. At sites that support redevelopment, storm water management may be more complex. For example, a containment site that supports multiple athletic fields may require cover system slopes that are shallower or configured much differently than would typically be the case.

Exhibit 3-4: Standard Slopes of Recreational Fields

Sport	Slope
Baseball/Softball	0.5 to 1.0%
Basketball	1.0 to 1.5%
Football/Soccer (Natural Turf)	1.5 to 2%
Tennis	0.5 to 1.0%

EPA guidance on cover systems indicates that the final top or upper layer of a cover system, after allowance for settlement, should have a slope of between three and five percent to maintain effective drainage.[15] However, a slope of three percent or more is usually not conducive to recreational use. Generally, developers of recreational fields prefer a surface grade of one to two percent for athletic fields in order to minimize field slope and still maintain positive drainage. **Exhibit 3-4** lists standard slopes for several types of sports fields.[16] To accommodate the recreational needs while maintaining the integrity of the cap, the surface of a cover system may be minimally sloped to support recreational activity while internal drainage or other layers are more steeply sloped to satisfy regulatory criteria and functional needs. Flat areas on the cover system are often avoided because of the potential for ponding of water which can negatively impact the function of the remedy. For example, surface water infiltration into the cover can increase and the field and cover system are susceptible to damage if played on in wet conditions.

Typically, developers of sports fields on Superfund sites have worked with EPA to design the slope of a cap in a way that minimizes the elevation differences along the direction of play. For example, if a football field were uniformly sloped at 1.5% from end to end, one goal line would be about 4.5 feet higher than the other. In a situation such as this, developers would prefer to orient the field and direction of play perpendicular to the slope. In the case of the football field, the change in elevation from sideline to sideline for a 1.5% slope would be about 2.25 feet. The field could be crowned along the centerline of play with uniform slopes extending 10 to 15 feet beyond the playing field boundary.

[15] U.S. EPA, Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments, 1989 (EPA 530/SW-89/047).

[16] Carpenter (1976).

Smaller fields or courts could be placed on built up areas on the cover system to prevent surface run-on and accommodate flatter slopes. However, general cover system grading needs or costs may preclude this alternative for larger fields or multiple field complexes.

Reuse features can also significantly alter surface water runoff characteristics. For example, an asphalt parking lot can generate a larger quantity of runoff in a shorter period of time than a similar sized and configured vegetated surface. In contrast, it is possible that a relatively porous surface, such as a crushed rock parking lot, will result in decreased runoff and increased surface water infiltration into the cover system. Features such as these and their corresponding effects may require modification to the cover systems design. Additional drainage channels, swales, or storm sewers may be needed to efficiently collect and remove water from fields, parking lots, and other reuse areas where they otherwise would not be needed. In other cases, the location of drainage channels or other drainage features may be limited due to interference from reuse facilities or vice versa.

At the Chisman Creek Superfund Site in Virginia, a surface water collection system was developed using a concrete lined swale that collected storm water runoff and channeled it off the cap and into a neighboring creek. To accommodate athletic fields, the cover system and accompanying drainage swales in some areas were sloped as little as one percent. The swales were lined with concrete because grass-lined drainage swales could not efficiently remove storm water with the minimal channel grade.

Ensuring Cover System Integrity

With the recreational reuse of a waste containment area, special care is often necessary to ensure the integrity of the cover system to avoid possible accidental contact with people using the site. Maintaining the integrity of the cover system involves: (1) controlling whether and how recreational facilities on the surface penetrate the cover system; and (2) taking steps to prevent accidental intrusion into the cover system.

Controlling Cover System Penetration

Recreational sites generally have lighting, fences, signs, backstops, scoreboards, or similar features depending on the type of use. Foundations and supporting poles or structures for these features could penetrate the cover system and possibly extend into waste if standard construction techniques are used. For example, fence, backstop, and small scoreboard poles typically extend three to five-feet into the ground, which exceeds, or is comparable to, the thickness of many cover systems.[17] Light poles and other large structures can extend much deeper into the ground and could penetrate most cover systems. Because penetrations can provide a conduit for gas and water movement, their use must be carefully

[17] Prince William County (1996); and Pioneer Manufacturing Co. (Cleveland, Ohio), 1999.

considered and proper steps must be taken to ensure the integrity of the cover system (e.g., using properly engineered seals or controls utilized to prevent the migration of gas or water).

One approach to avoid penetrating the cover is to increase the thickness of cover system layers so that shallow foundation systems are located above critical components of the cap. Footings located at shallower depths may be an option for fences and other relatively small features. The use of "sleeves" may also be considered to minimize disruptions to critical cover system components during removal and replacement of poles and other support structures. For example, a football field may have goal posts that are replaced periodically. Instead of creating new cover penetrations or causing other damage from replacement activities, the old pole could be slipped out of the sleeve and a new one installed. If structures are in contact with waste, their resistance to damage from contaminants is usually evaluated.

Avoiding Accidental Intrusion

Unauthorized digging or intrusive repairs or improvements may occur periodically at reuse sites. The use of warning or barrier layers, therefore, are often considered to minimize damage to critical cover system components and encroachment into waste. Visible barriers, such as colored geotextiles or other synthetic layers, can be placed in the upper portion of the cover system to serve as a warning to workers that additional digging can result in damage to underlying layers and exposure of waste or contaminants. A visible layer can also be used under high activity or non-vegetated areas such as paths or infields to identify regions where soil has eroded to a point where repair is necessary.[18]

A more robust barrier, commonly referred to as a biota-barrier, may be necessary to prevent digging activity by animals, the public, and unauthorized construction activities. Depending on the situation and anticipated intruder (e.g., children or animal) an appropriate barrier layer might range from a geogrid or other geosynthetic to gravel or cobbles. The barrier will be most effective if it is separated from the critical components of the cap or is thick enough to withstand a limited degree of intrusion. For example, at the Cohen Property Superfund site in Taunton, Massachusetts, a salt storage area was constructed over lead contaminated soils. High visibility orange fencing was placed over the contamination to mark the beginning of contaminated soil and to serve as a warning against encroachment. A hazardous waste landfill in Colorado will use recycled crushed concrete from an abandoned airport runway as a biota-barrier to prevent possible intrusion from badgers and other burrowing animals.

In addition to barriers, registering the site with the county or state "one call system" typically used to locate subsurface utilities prior to construction is an alternative method to ensure that no one inadvertently excavates waste containment areas. Markers could be placed on the site reminding workers to use the "one call" system before taking actions that may degrade the containment system or expose them to the contained waste.

[18] Mackey (1996)

Other Design Considerations

Most recreational uses are accompanied by support facilities, such as buildings, utilities, and paved surfaces, such as parking lots. The construction of support facilities on a waste containment area must be considered during the design and construction of the remedy. The following sections provide information on the remedial design issues to be considered when the recreational use of the site includes support facilities.

Buildings

Most recreational areas have buildings and supporting utilities that are used for concession stands, restrooms, maintenance facilities, or other purposes. For the most part, these are small and lightly loaded structures. However, most closed landfills do not have buildings located over waste because of design issues that include accommodating settlement, off-gas management, and foundation incompatibility with cover system components. If a building must be located on the cover system to support the planned reuse, temporary or moveable structures such as small sheds or trailers used in place of permanent structures have proven to be effective.

Differential settlement can cause significant structural damage to buildings, rendering them unusable and unsafe. Placement of permanent buildings over unstable areas is generally avoided unless subsurface conditions are improved, or foundation and structural systems are designed to accommodate large movements. Deep foundations (e.g., piles) or oversized and heavily reinforced shallow foundations may be necessary, even for lightly loaded structures, because of settlement or other foundation concerns. Although these types of foundations may limit total and differential settlement of the structure to acceptable levels, their impact on other aspects of the project needs to be considered. For example, a structure supported on piles and constructed on a landfill may experience less settlement than the surrounding ground. Over time, the structure can become partially or fully elevated above the ground surface which is unsightly, can result in damage to supporting utilities and access features, and require periodic maintenance.

Foundations, even shallow foundations, typically extend to a depth that is greater than the thickness of conventional cover systems. This is particularly true in cold climates where foundations are typically required to be located below the frost zone. Foundation systems that penetrate cover system components, particularly barrier layers, can provide preferential flow paths for the downward movement of liquids or the upward movement of gases, either of which can adversely affect the performance and safety of the remedy or structure. As a general rule, penetrations of the cover system are avoided to the extent possible. If they are necessary, appropriate measures are taken to seal the penetration to prevent liquid and gas movement. Seals also need to be able to tolerate the effects of differential settlement to prevent tearing and rupture. Where a shallow foundation will suffice, the thickness of the cover soils could be increased to avoid penetrating barrier layers or other critical components of the cover system.

The potential accumulation of toxic or explosive gases inside structures can also make them dangerous and unusable. Because the public will use, or have access to, many of the structures at recreational reuse sites, an extra degree of caution is appropriate and redundant gas-management features may be necessary. This may entail gas collection and monitoring systems that are independent of other such systems at the site. For example, a building on a site with a site-wide landfill gas collection system may have a dedicated monitoring system for the structure. In addition, the building could be designed to minimize the accumulation of gases in the structure. Automatic air monitoring systems and alarms are often considered for any structure that is located in gas producing areas.

Utilities

Most recreational areas will require some level of utility service to support field lighting, bathrooms, concession stands, and other reuse features. Typical underground utilities include sanitary sewers, potable water, and natural gas systems. Telecommunication (e.g., phone and cable) and electrical lines can be either buried or located above ground. However, even above ground utilities require poles or other supporting mechanisms that extend some depth into the ground. Any such buried structure can potentially conflict with critical cover system components and impact the effectiveness of a remedy. For example, leakage from a sanitary sewer located above a cover system's barrier layer might be captured by the cap's internal drainage system and cause excessive bio-fouling of the drainage media. A leaking potable water line located within waste below a cover system's barrier layer could result in an increase in the quantity of leachate that is being generated. Repairing or upgrading the water line would also require disruption of the cap and expose waste. As these examples illustrate, utilities must be designed and located with the same considerations as other features of the remedy.

Workers install lights for sports fields during construction of the cover system at the Chisman Creek Superfund site in Yorktown, Virginia, a former fly ash disposal area.

Sewers, water lines, and gas distribution systems generally are located in areas where large settlements are anticipated. Differential movement can result in broken or cracked piping and an uncontrolled release of the media that are being carried. When used in areas that will experience differential settlement, piping is often designed to accommodate some movement by using ductile materials, flexible connections, and similar features. For pressurized water and gas systems, automatic monitoring devices and shut-offs are considered to prevent large uncontrolled releases. Gravity sewers and other non-pressurized systems could also be designed for easy monitoring. For example, double-walled piping equipped with an interstitial leak detection system could be used. Another example of a possible monitoring system consists of wrapping a utility trench's pervious backfill with a geomembrane and sloping the trench to direct flow to monitoring sumps. The sumps could be periodically checked for liquids. Any monitoring system will have advantages and disadvantages related to cost, implementability, function, performance and maintenance. The need for and type of monitoring required will be decided on a site-specific basis.

The use of clean utility corridors and building pads have proven to be effective in minimizing the potential for workers to encounter waste or contaminants during repairs of, or modifications to, underground utilities, process piping, or other features. In this approach, utilities and similar underground features have been placed in oversized trenches and backfilled with uncontaminated or "clean" soils. The additional width and depth of the clean trenches limits the possibility that waste will be encountered or critical cover system components damaged during future excavations. Clean building pads could be constructed for the same purposes. These methods were utilized for utility trenches installed at the Chisman Creek Site in Virginia and the Cohen property site in Massachusetts. To accommodate future development and minimize future exposure to waste or contaminants, clean utility corridors and building pads could also be installed during initial construction. Detection tape, surface monuments, and other methods of marking the alignment or limits of trenches and building pads could be considered to facilitate locating these features in the future.

<u>Paved Surfaces</u>

Almost all reuse sites will include paved surfaces that will be used as parking lots, sidewalks, roads, trails, support areas, and other purposes. In some cases, the pavement may be an integral part of the remedy. For example, at the Rhone-Poulenc, Inc./Zoecon Corporation Superfund site in East Palo Alto, California, paved surfaces are the sole hydraulic barrier to prevent water from

**Example of Use of
Paved Surface as a Cover System**

At the Rhone-Poulenc, Inc./Zoecon Corporation Superfund site in East Palo Alto, California, paved surfaces have been used as the sole hydraulic barrier to prevent water from percolating into waste. Engineers designed a cap that utilized three layers of asphaltic concrete placed over soil that had been deep-mixed with Portland cement and silicates. The top layer consisted of a conventional dense-graded asphalt which is similar to that used for heavy-duty highways and industrial pavements. The middle layer consisted of asphalt with a high percentage of air voids that acted as a drainage layer and the bottom layer consisted of hydraulic asphalt (asphalt with a higher tar content to reduce air voids) to prevent percolation of liquids into the waste.

A parking lot for the sports fields at the Chisman Creek site in Yorktown, Virginia, was built over a portion of the cover system.

percolating into waste.[19] A paved surface can also be designed to function as both a cover system's barrier layer and a parking lot. For example, the containment portion of the site may be used for parking while the rest of the site is developed into recreational areas. In most cases, however, paved surfaces are used solely to support the reuse activity and are not integral features of the remedy. The materials used to construct pavement, and the location of the pavement relative to the cover system, need to be carefully considered during planning and design due to the potential for damage from subsidence and differential settlement. Other factors to consider when selecting a pavement include cost, loading, durability, and long-term maintenance.

Pavement is susceptible to varying degrees of damage from a number of mechanisms depending on the materials used. At containment sites, perhaps the most significant mechanism for damage is related to differential settlement. The three principal surfacing materials — asphalt, concrete, and crushed rock — will accommodate differing levels of settlement.

Asphalt has proven to be an effective surface pavement for final covers, particularly when a limited amount of subsidence and differential settlement is anticipated.[20] The flexibility of asphalt allows the material to deform to some extent which minimizes cracking and other types of damage. In addition, depression or sunken areas can be returned to grade by placement of additional material, and damaged areas can be replaced relatively quickly and easily. However, asphalt surfaces can become non-functional due to excessive cracking, depressions, and other types of damage resulting from poor foundation conditions or excessive settlement. Asphalt pavements also require maintenance, such as new top coatings, on a regular basis.

Concrete has a limited ability to accommodate subsidence and differential settlement and is generally not used as a pavement on cover systems. Concrete will experience significant damage (e.g., cracks and displacements) when foundation support is poor. The appearance of cracks will facilitate additional damage from mechanisms such as freeze-thaw. Unlike asphalt or crushed rock, repair or replacement of concrete pavements can be expensive and time consuming. Although not recommended for use on cover systems where settlement is anticipated, concrete pavements may be effectively used on other portions of a site.

---

[19] Roger Smith, "Asphalt Pavement Doubles as Hazardous Soils Cap and Loading Area." Asphalt, 9 (Winter 1995/1996).

[20] M. Keech, "Design of Civil Infrastructure Over Landfills." In Landfill Closures, American Society of Civil Engineers (1995).

Crushed rock or gravel surfacing is superior to either asphalt or concrete in terms of its ability to handle differential settlement. Because crushed rock is not rigid like concrete, it can withstand significant deterioration before its function as a pavement is impaired from potholes, depressions, or other deformations. Any areas that do experience damage can be quickly and easily repaired by the placement of additional rock. Crushed rock surfacing is commonly used for access roads and support areas at Superfund sites and for roads and parking lots at recreational areas. It is used in these kinds of applications because of the relatively light loads that will be supported, limited traffic volume, material durability, and low cost.

Section 4.
Operation and Maintenance

Following the completion of construction activities, and any sampling that may be performed to ensure the cleanup achieves its remedial objectives and is protective of any future use, a waste containment site enters into the operation and maintenance (O&M) phase. O&M encompasses a wide range of activities, including caring for cover system vegetation, operating landfill gas or groundwater collection and treatments systems, sampling and monitoring various media (e.g., air, water, soil), performing annual and special inspections, and making necessary repairs or upgrades to remedy features. All containment remedies require some form of O&M on a continuing and regular basis due to normal operations or wear and tear. At recreational reuse sites, O&M is especially important due to the increased use of the site and the potential for damage to the remedy from that use. Properly implemented O&M is necessary to ensure that the remedy functions properly and protects human health and the environment.

An O&M plan is developed and implemented at every Superfund site. RPMs may consider holding additional meetings with the state and those responsible for carrying out or paying for O&M activities when developing the O&M plan for a waste containment site that will be reused. Typically, the plan is comprehensive and includes a discussion of the roles and responsibilities of the various parties involved. In addition to specifying typical O&M requirements, such as the frequency of maintenance activities, sampling, and inspections, the plan may address limitations or special considerations related to the reuse activity. For example, to prevent damage to a containment site's cover system at a recreational reuse site, the O&M plan may require controls on play or turf care practices that are more stringent or involved than those required at other recreational complexes. The O&M plan may also include requirements for documenting and reporting maintenance related activities that occur at the site. This information typically would be included in an annual report that is distributed to interested parties and regulatory agencies. Quality control and quality assurance systems are also established and implemented to ensure that O&M is being performed satisfactory.

Additional meetings between EPA, the state, and those parties responsible for carrying out O&M activities may be considered when developing an O&M plan for a site that will be in reuse. At redeveloped sites, responsibility for implementing and paying for O&M may be split among various parties. When splitting O&M responsibilities, it is essential that roles and responsibilities are clearly delineated in enforceable agreements and specified in an O&M plan. For example, at the Chisman Creek Superfund Site, York County is responsible for maintaining the sports fields and conducting other ordinary O&M activities. Mowing the grass and performing routine repairs are tasks that the county performs as part of their normal park maintenance operations. This has, in effect, eliminated the need for the state or PRP to conduct routine O&M activities at the site. However, the PRP retains responsibility for major cover systems repairs.[22]

In some situations, a local entity that is not familiar with requirements typically associated with O&M at Superfund remedies or with the additional requirements resulting from recreational reuse may be tasked with site maintenance. In these cases, it is critical that O&M personnel are properly trained to perform the work and to recognize hazards at the site and indications of remedy distress. It is important that those involved with the long-term care of a Superfund site understand the limitations and potentially hazardous nature of some aspects of the site and remedy, and that proper precautions are taken and appropriate procedures followed. For example, at many sites, only properly trained personnel are involved with activities that may encounter waste because of the potential for exposure to contaminants. Similarly, the improper operation of treatment systems can result in contaminant releases above specified levels, damage to the system, and an unsafe working environment.

As noted above, the O&M plan contains requirements for performing annual and special inspections and sampling to determine if the remedy is functioning properly. In addition to these inspections, EPA conducts an in-depth review of the remedy at least every five years for any site where the remedial action leaves hazardous substances, pollutants, or contaminants on-site above levels that allow for unlimited use and unrestricted exposure. The two products of this review include: (1) an analysis and report that determines whether the remedy is still protective of human health and the environment; and (2) a list of additional maintenance activities that need to be performed to ensure continued protectiveness and the parties responsible for performing those activities. At Superfund sites where reuse is occurring, these type of inspections, reviews, and determinations are particularly important given the potentially intensive public use of the site.

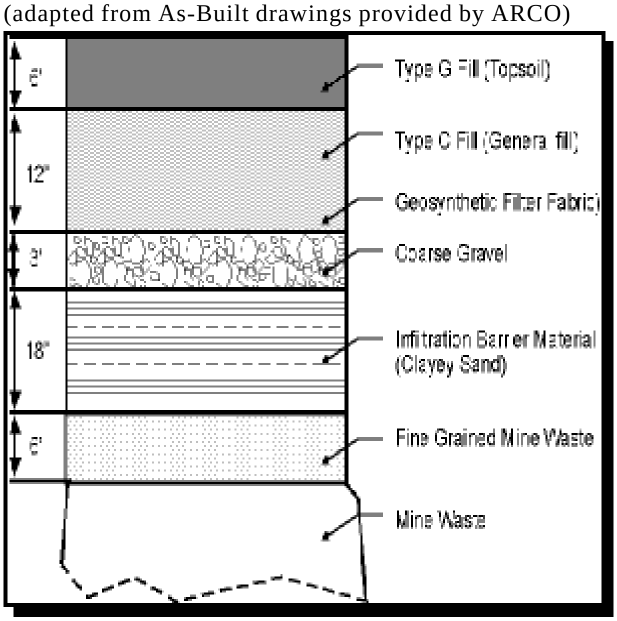
[22] U.S. EPA, Reuse of CERCLA Landfill and Containment Sites, 1999 (EPA/540-F-99-015).

Section 5.
Case Studies

Timber Butte Youth Park (Silver Bow Creek Superfund Site)
Butte, Montana

The Timber Butte Youth Park is under construction atop 1.4 million cubic yards of mine tailings at the 80-acre Clark Tailings area at the Silver Bow Creek Superfund site. Site contamination is the result of over 100 years of mining process operations in the area. Until the early 1970s, mining, milling, and smelting wastes were dumped onto the site. A cover system was constructed over the 80-acre area to protect the public from exposure to the mining waste and was designed to support athletic fields. Adjacent to the covered mine tailings is the closed Butte-Silver Bow Landfill, which is being developed into a golf driving range.

Cross Section Diagram of Clark Tailings Operable Unit Cover System
(adapted from As-Built drawings provided by ARCO)



Site Settlement: Designers of the Timber Butte Youth Park located the athletic fields on the covered mine waste, where little settlement is expected. Since settlement is expected at the closed Butte-Silver Bow Landfill, this area was selected for the golf driving range. Settlement of the waste beneath the driving range will not affect play or present a tripping hazard to users.

Cover System Design: Six inches of high quality topsoil was taken from nearby borrow areas for the surface layer of the Clark Tailings cap to support turf grass for athletic fields. Design engineers included a capillary break in the cover system that will support the park. The capillary break, which is a coarse gravel layer, confines water in the fine grained vegetative support soils. This provides the park grasses with the moisture they need within the rooting zone without excessive irrigation, which reduces the amount of leachate generated. A geotextile overlies the gravel layer to prevent the upper fined grained soils from migrating into the gravel.

Gas Collection: Design engineers installed passive gas vents at the closed municipal landfill area as far away as possible from the tee boxes at the golf driving range. It has been suggested that the gas vents be disguised as distance markers for the driving range. The covered mine waste is not expected to generate gas.

Operation & Maintenance and Institutional Controls: ARCO is currently responsible for O&M at the site but will transfer responsibility for maintaining the athletic fields and driving range, which will also serve to maintain the cover system, to the City of Butte. By 2004, the City of Butte will also be responsible for maintaining the entire site with financial assistance from a trust fund set up by ARCO. ARCO will always retain responsibility for addressing issues with the cover system, such as cap failure or improper cap design. Institutional controls include a notation on the deed that mine waste is contained on site, restrictions on well drilling and groundwater use, and prohibition of future uses that might damage the cover system. Public access to areas where passive methane gas vents are located is also restricted.

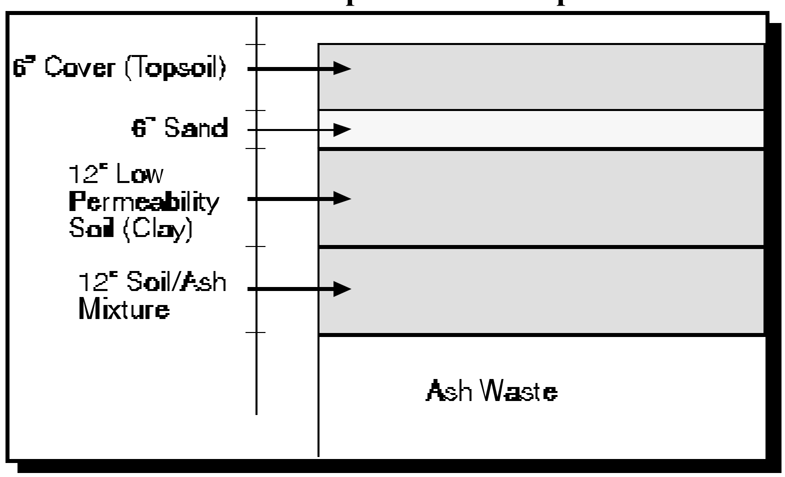
Enhancement: The enhanced cover system design, athletic fields, and golf driving range were financed by Atlantic Richfield Company (ARCO), the major PRP at the site, so no costs were incurred by EPA to support reuse of the site. In return for financing the park, the PRP will transfer the title to the property and operation and maintenance of the cover system to the City of Butte.

Chisman Creek Superfund Site
Seaford, Virginia

The Chisman Creek Superfund site now supports a 27-acre lighted sports complex atop capped fly ash. From 1957 to 1974, Virginia Electric & Power Company contracted with a local trucking company to dispose of 500,000 tons of fly ash generated by their Yorktown generating plant at the site. Investigations of contamination began in 1980 following citizens' concerns about discolored well water, which revealed heavy metal contamination in groundwater and Chisman Creek. A cover system was constructed to contain the fly ash and prevent additional migration of heavy metals from the ash into ground and surface water.

Site Settlement: Designers of the Chisman Creek Site expected little settlement due to waste characteristics, depth of waste, and the amount of time that had elapsed since deposition.

Cross-Section Diagram of the Chisman Creek Superfund Site Cap



Cover System Design: The cover system consists of one foot of a soil/ash mixture, one foot of clay, six inches of sand and six inches of topsoil. Utility trenches were installed in the cap to support park lighting and irrigation. The utility trenches were constructed so that at least two feet of clean fill surrounds installed utilities to prevent future maintenance workers from contact with the covered fly ash. Prior to constructing the cover system, the fly ash was sculpted to support the planned athletic fields.

Operation and Maintenance: Site maintenance such as mowing the grass, preventing cover system erosion, and repairing site improvements is handled by York County as part of their normal park operations. The Virginia Electric & Power Company leases the property to the York County Parks Department for the yearly property tax value. In return, the Parks Department performs routine maintenance including mowing the lawn, upkeep of the fields and sprinkler systems. Any work resulting from cap failure, improper cap design and the operation and maintenance of the dewatering system and treatment of water is the responsibility of Virginia Power. One such incident occurred shortly after the park opened where uneven settling caused a pool of water to form on one of the fields. This was considered a cap design issue and taken care of by Virginia Power.

Enhancement: The Chisman Creek site was redeveloped at no additional cost to EPA. Virginia Power financed the construction of the cover system and graded the site to support recreational fields. York County constructed the fields, which it operates and maintains.

Ohio River Park Superfund Site
Neville Island, Pennsylvania

The 32-acre Ohio River Park Superfund Site in Neville Island, Pennsylvania, is now home to the Island Sport Center, a multimillion dollar sports and entertainment complex. A municipal landfill operated on the property from the 1930s until the 1950s. From 1952 to the mid-1960s, the Pittsburgh Coke & Chemical Company disposed of industrial waste on the property, causing widespread contamination of the soil, surface water, and groundwater. As part of the remedy, the PRP, under the oversight of EPA, placed a protective cover over the landfill to protect the public from exposure to the industrial waste and developed the site into an athletic and entertainment facility, which includes an indoor ice-skating and hockey complex (indoor ice rink, and external ice rink/field courts) on the northeast portion of the property, a golf complex (driving range, exterior miniature golf course, and interior golf center) on the central-western portion of the property, and a theater complex and restaurant on the extreme western tip of the site.

Site Settlement: The sports complex includes several areas where site subsidence and differential settlement were a concern. For the portion of the site that supports the golf dome, the PRP first pre-loaded the area with several hundred tons of fill material and monitored the settlement until it ceased. The PRP also contoured the site and placed additional clean soil over areas targeted to support heavy cement foundations for the dome. The additional soil would allow for some differential settlement to occur without the waste below being disturbed. The cement foundations used to stabilize the dome were constructed of wide flat cement blocks, which distribute the mass of the block over a greater surface area and reduce the likelihood of differential settlement.

For the portion of the site that supports a restaurant and two ice rinks, the PRP installed piles that were driven 60 feet down into bedrock. A total of 412 piles were needed to support the restaurant and skating facility. Although other, less expensive engineering techniques could have been used to build the foundation, the use of piles driven into bedrock eliminated the possibility that differential settlement would adversely affect the structures.

Cover System Design: Areas in which there was a high concentration of waste were covered with a multi-layer cap to prevent further contamination of groundwater. The multi-layer cap includes a subgrade layer, a barrier layer, a drainage layer, and a vegetative cover layer. The subgrade layer consists of engineered fill and a liner foundation and provides a firm foundation for the barrier layer construction, as well as an adequate slope to ensure drainage from the drainage and vegetative layers. Engineered fill was placed six inches below the liner subgrade layer. The liner subgrade material is composed of fine-grained soil (silt and clay) that is free of any materials that might damage the overlying synthetic liner. The barrier layer consists of a high density polyethylene liner that is 40 millimeters thick. The drainage layer consists of a non-woven geotextile. Finally, the vegetative cover layer supports vegetative growth, provides frost protection, and minimizes the potential for damage from surface activities and root penetration.

The designers understood that some areas of the site are more susceptible to repairs than others. In areas where intrusive work might be needed, highly visible orange fencing was unrolled flat, over the waste, and tacked into the ground. Clean fill was then placed over the waste and fencing to provide a physical barrier. The orange fence acts as a visible barrier for future workers at the site. An erosion soil cap was then placed over the entire site, raising the ground system above the 100-year flood elevation. Two to eight feet of fill dirt (transported from off-site) was used for the soil cap and serves to prevent exposure to contaminants in the event of erosion of the cap. The slopes that were created by elevating the site were vegetated to prevent future erosion. Pruning and watering keeps the existing vegetation and slopes both healthy and stable.

Gas Collection: A gas collection and venting system was designed to collect excess gases beneath the multi-layer cap and passively vent the gases to the atmosphere. The gas collection and venting system consists of shallow gravel-filled trenches connected to a header along the crest of the liner subgrade layer and a series of vent pipes. A non-woven geofabric surrounds the trenches to prevent migration of fine-grained soil particles into the gas collection system. To hide some of the vents from the public, shallow root trees and bushes were placed around some on the vents.

Operation and Maintenance and Institutional Controls: Site maintenance is the responsibility of the PRP, who maintains the cover systems and monitors groundwater. Institutional controls restrict land and groundwater use at the site and reduce the potential for human exposure to contamination. Permanent signs were installed on the banks of the Ohio River to caution fishermen against eating bottom-feeding fish and a series of signs were installed to restrict access to the side slopes leading to the Ohio River and the Ohio River Back Channel (areas that did not receive additional fill placement or covering by roadways or buildings).

Enhancement: The Ohio River Site was redeveloped at no additional cost to EPA. The PRP financed the entire cost of construction for the multi-layer cap, the soil cap, and the Island Sport Center, including the internal and external ice rinks, golf complex, athletic fields, trails, and theater and restaurant. The PRP incurred additional costs to contour the site and pre-load areas to avoid differential settlement, and used engineering technologies that improved the performance of the remedy rather than using least costly alternatives. EPA oversaw the cleanup and redevelopment of the site, but did not incur additional costs for these activities.

Bibliography

Carpenter, J. D. 1976. Handbook of Landscape Architectural Construction. McLean, Virginia: Landscape Architecture Foundation.

Collins, P. 1998. "Superfund Success, Superfast." Civil Engineering (December).

Crowley, P. (Montana Department of Environment, Solid Waste Division). 1999. Personal Communication.

Crowcroft, P. H. 1996. "Promoting Landfill Stabilisation and Controlling the Consequences." Polluted & Marginal Land - 96, Proceedings of the Fourth International Conference on the Re-use of Contaminated Land and Landfills.

Emberton, J. R. and Parker, A. 1987. "The Problems Associated with Building on Landfill Sites." Waste Management & Research, vol. 5, 473-482.

Fogg, G. 1997. Park Planning Guidelines, 3rd Edition. National Recreation & Park Association.

Golden, M. 1993. "Pros and Cons of Developing Recreational Facilities on Closed Landfills." Proceedings of the International Conference on Marinas, Parks, and Recreation Developments, 257-260.

Hall, R., et al. 1996. "Re-use of Landfills." Polluted & Marginal Land - 96, Proceedings of the Fourth International Conference on the Re-use of Contaminated Land and Landfills.

Keech, M. 1995. "Design of Civil Infrastructure Over Landfills." In Landfill Closures. New York: American Society of Civil Engineers.

Kissida, J., et al. 1991. "Landfill Park: From Eyesore to Asset." Civil Engineering (August), 49-51.

Koerner, R. M., and Daniel, D. E. 1997. Final Covers for Solid Waste Landfills and Abandoned Dumps. Reston, Virginia: American Society of Civil Engineers.

Mackey, R. E. 1996. "Three End-Uses for Closed Landfills and Their Impact on the Geosynthetic Design." Geotextiles and Geomembranes, vol. 14, 409-424.

Naber, T. 1987. "Today's Landfill is Tomorrow's Playground." Waste Age (September), 46-58.

Patch, J., et al. 1996. "Foundation Engineering on Contaminated Land Sites." Polluted & Marginal Land - 96, Proceedings of the Fourth International Conference on the Re-use of Contaminated Land and Landfills.

Pioneer Manufacturing Co. (Cleveland, Ohio). 1999.

Paukstis, S. 1993. "Landfill Transformed into Recreation Area." American City & County (June), 30.

Prince William County. 1996. Design Standards.

Puhalla, J. 1999. Sports Field Design and Construction. Michigan: Ann Arbor Press.

Sachs, J. 1997. "At Play on a Field of Trash." Discover (June), 55-59.

Schlect, E. 1996. "Tacoma Asphalt Cap is Tough and Impermeable." Asphalt, vol. 5, no. 1 (Summer).

Smith, Roger. 1995-1996. "Asphalt Pavement Doubles as Hazardous Soils Cap and Loading Area." Asphalt, vol. 9, no. 3 (Winter).

Soccer Industry Council of America. 1998. Soccer Planning System: A Guide for Community Soccer Center Management.

Spreull, W. J. and Cullum, S. 1986. "Landfill Gas Venting for Agricultural Restoration." Waste Management & Research, vol. 5, 1-12.

U.S. Product Safety Commission, Office of Information and Public Affairs. "Handbook for Public Playground Safety." Publication no. 32.

U.S. EPA. 1979. Design and Construction of Covers for Solid Waste Landfills, EPA 600/2-79/165.

U.S. EPA. 1980. Evaluating Cover Systems for Solid and Hazardous Waste, EPA 530/SW-867c.

U.S. EPA. 1983. Standardized Procedures for Planting Vegetation on Completed Sanitary Landfills, EPA 600/2-83/055.

U.S. EPA. 1985a. Covers for Uncontrolled Hazardous Waste Sites, EPA 540/2-85/002.

U.S. EPA. 1985b. Settlement and Cover Subsidence of Hazardous Waste Landfills, EPA 600/2-85/035.

U.S. EPA. 1987a. Engineering Guidance for the Design, Construction, and Maintenance of Cover Systems for Hazardous Waste, EPA 600/2-87/039.

U.S. EPA. 1987b. Prediction/Mitigation of Subsidence Damage to Hazardous Waste Landfill Covers, EPA 600/2-87/025.

U.S. EPA. 1989. Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments, EPA 530/SW-89/047.

U.S. EPA. 1991. Seminar Publication: Design and Construction of RCRA/CERCLA Final Covers, EPA 625/4-91/025.

U.S. EPA. 1995. Presumptive Remedies: CERCLA Landfill Caps RI/FS Data Collection Guide, EPA 540/F-95/009.

U.S. EPA. 1999. Reuse of CERCLA Landfill and Containment Sites, EPA/540-F-99-015.

U.S. EPA. Reusing Cleaned Up Superfund Sites: Use of Land Above Hazardous Waste Containment Areas for Commercial and Light Industrial Facilities (Planned 2001).

U.S. EPA. Reusing Cleaned Up Superfund Sites: Use of Land Above Hazardous Waste Containment Areas for Golf Facilities (Planned 2001).

U.S. EPA. Technical Guidance for RCRA/CERCLA Final Covers (Planned 2001).

U.S. EPA. Reusing Cleaned Up Superfund Sites: Ecological Use of Land Above Hazardous Waste Containment Areas (Planned 2001).